Four models out of 16 made the cut for best in field

**Practice recommendation**

Four tympanometers are suitable for outpatient primary care, and each has positive and negative attributes. The Earscan was rated easiest to use and provided the most consistent data.

In a primary care setting where patient volume, time constraints, and provider turnover are on the increase, you need dependable biomedical equipment that produces quality data and is easy to use, ergonomic, and affordable. This is certainly true of the tympanometer, which is used to measure mobility and impedance of the tympanic membrane and ossicles, provide an objective measurement of the middle ear, augment visual and pneumatic otoscopy, and confirm and document otitis media with effusion (OME) and acute otitis media (AOM).1–3 Our study aimed to determine which tympanometer is optimal in the outpatient primary care setting.

Based on objective and subjective analysis, the Earscan appears to be an excellent choice for outpatient primary care, though users also liked the MT 10 and GSI 37.

**Four units made initial cut**

Of 16 tympanometers we found through a review of market literature, an Internet search, and audiology recommendations, 4 met the minimum requirements (Table 1)—Earscan (www.microaud.com), GSI 37 (www.viasyshealthcare.com), MicroTymp 2 (www.welchallyn.com) and MT 10 (www.interacoustics-us.com).

**What we looked for in our in-depth evaluation**

We evaluated the tympanometers with formal objective testing, clinical use, subjective user rating, and feature comparison.

We assessed reproducibility with a volume calibration tool (in vitro), and with intra- and inter-device testing (in vivo) on volunteers. The tympanometers were also compared side by side in a clinical setting on adults and children with and without ear disease.

Eight evaluators with various clinical and technical backgrounds were our subjective raters. They used a Likert scale survey to rate the following tympanometer attributes: appearance, size, safety, durability, capabilities, ergonomics of physical design, ease of use (overall operations, specific control features), screen information layout, LCD screen/monitor, printing, maintenance, software interface, data quality and reliability, and accessories. Participants independently reviewed the tympanometers and were blinded to others’ evaluations.
We prioritized categories as high, medium, or low importance. Finally, important features of each unit were identified and verified.

**Our rankings**

**Earscan comes out on top**

Formal testing, clinical use, and feature comparison suggest the Earscan is the tympanometer best suited for primary care (see “How the units compared,” page 948).

The Earscan delivered high-quality data with excellent results in reproducibility testing for volume, pressure, and compliance. It proved reliable in the clinical setting with positive comments from participants.

**Ergonomics.** The Earscan was rated the easiest to use and the simplest to obtain a probe tip-ear seal. The Earscan has a small cylindrical probe affixed to a pressure/sound tube that attaches to the control unit. Anecdotally, these kinds of box-and-tube tympanometers provide the best seal and true readings. The probe is small, lightweight, and well suited for the clinician’s hand and patient’s ear so the tip-ear seal is easily viewed during the procedure. The tips are malleable, beveled, and tapered to provide an excellent fit in the ear canal.

The control unit is a reasonable size with finger-sized buttons and a viewable screen. It is simple to turn the unit on, press the Impedance button and perform the exam. The unit displays understandable feedback as to status.

**Construction.** The air pump, tone inducer, tubing, probe, and compliance pressure sensor are sturdy and yield consistent results. The unit is rugged and portable making it popular for occupational health.

**Features.** The Earscan is affordable and comes with additional functionality of audiometry and acoustic reflex testing. It has RS232 serial port capability to facilitate printer and limited computer integration.

**Drawbacks.** The unit is powered by a 120-volt adapter, making it less convenient than a handheld tympanometer. It may not be reasonable to carry the Earscan from one exam room to another. The Earscan has an older appearance with sealed buttons that are encased and provide little tactile feedback.

**When other units may be preferable**

If a handheld tympanometer with a docking station is necessary, then the MT10 or GSI 37 would be an appropriate choice.

**MT10.** This unit received the highest overall user ratings, slightly higher than the Earscan. The MT10 has a larger monitor and better control features than the GSI 37. It also has the capability for computer integration. However, the MT 10 gave less consistent readings for same-ear measurements when compared with the Earscan and GSI 37.

**GSI 37.** This unit provided more consistent pressure and compliance readings than the MT 10, and had no glare on its screen. It also has a longer track record in the field than does the newer MT10. It has an excellent operation manual.
How the units compared

In vitro testing for volume using a fixed object (calibration tube) demonstrated excellent reproducibility. There was little to no variation for 10 consecutive measurements for each tympanometer. In vivo reproducibility testing was performed taking 3 consecutive readings on each of 5 different ears using the tympanometers. For Compliance and Pressure readings the Earscan showed the most consistency while the MT 10 showed the least (TABLE 2).

Compliance data is graphed from 1 left ear to portray the range of values obtained from 4 tympanometers (FIGURE 1). While all tympanometers gave normal compliance readings, some units were less consistent than others. The MT10 showed the widest range of readings (least consistency). For this patient’s right ear (not shown), 3 tympanometers identified an overly compliant ear drum, while the MT10 gave normal and close to normal values. The MicroTymp 2 did not provide a compliance reading for the right ear.

Middle ear pressure data is graphed from the same left ear to portray the range of values obtained from 4 tympanometers (FIGURE 2). All 4 units gave values within normal range; there was a wide range from the MT10 and MicroTymp 2.
Which tympanometer is optimal for an outpatient primary care setting?

Earscan was most consistent for compliance and pressure readings; MT 10 was least consistent.

Figure 3

Earscan tympanograms agree with corresponding video otoscope images

Top: Earscan demonstrating a normal left tympanogram and corresponding video otoscope image. Bottom: Earscan demonstrating an abnormal right tympanogram with elevated middle ear pressure, reduced compliance and reduced physical volume. The video otoscope image is consistent with otitis media.

nometers (Figure 2). Overall, the units gave values that were within the clinically acceptable range of normal. However, there was a wide range of readings from the MT10 and MicroTymp 2. Assuming the participants’ middle ear pressure was truly close to zero, the outlier values reported by the MT10 and MicroTymp 2 might have clinical significance.

More than 100 tympanograms were obtained on children and adults; observations were noted. The Earscan, GSI 37 and MT 10 were easier to use and to obtain a good seal. The MicroTymp 2 proved more difficult to obtain a seal with and at times presented a falsely positive flat tympanogram. Earscan and MT10 gave similar readings on several occasions. On several occasions, the MicroTymp 2 and GSI 37 values significantly disagreed with each other. At times the MicroTymp 2 provided a graphical tympanogram but did not provide the numerical data. It was also easy to inadvertently combine previous data from one ear with new data from contralateral ear when using the MicroTymp 2.

Earscan tympanograms and corresponding video otoscope images are shown in Figure 3. The right tympanogram (bottom) is consistent with the video otoscope findings of otitis media. Observe the low compliance, elevated middle ear pressure, and low physical volume. The normal left tympanogram and otoscopy are concordant.

User ratings are shown in Table 3. Overall, participants ranked the MT10 highest (56.3) with the Earscan second (54.9), GSI 37 third (50.4), and MicroTymp 2 fourth (46.0). The MT10 rated highest in Ergonomics, Ease of Use of Control Features, Screen, Accessories, Appearance, Size and Information Layout. The Earscan rated highest in Overall Ease of Use and Perceived Durability. The MT10 and Earscan were tied for Capabilities and Interfacing. The MT10, GSI 37 and Earscan were tied for Perceived Data Quality. The GSI 37 was rated highest in Perceived Maintenance. Seven out of 8 reviewers (2 ties with the
### TABLE 3

**User ratings of 4 tympanometers (Likert scale 1 to 5)**

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>EARS CAN</th>
<th>GSI 37</th>
<th>MICRO TYMP 2</th>
<th>MT10</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Categories deemed highest importance</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ease of use: overall</td>
<td>4.1</td>
<td>3.8</td>
<td>3.0</td>
<td>3.8</td>
</tr>
<tr>
<td>Data quality</td>
<td>4.4</td>
<td>4.4</td>
<td>4.0</td>
<td>4.4</td>
</tr>
<tr>
<td>Ergonomics</td>
<td>4.5</td>
<td>4.6</td>
<td>4.4</td>
<td>4.0</td>
</tr>
<tr>
<td>Durability</td>
<td>4.9</td>
<td>4.3</td>
<td>4.4</td>
<td>4.6</td>
</tr>
<tr>
<td>Maintenance</td>
<td>4.7</td>
<td>4.8</td>
<td>3.7</td>
<td>4.4</td>
</tr>
</tbody>
</table>

| **Categories deemed medium importance** |          |        |              |      |
| Ease of use: controls                 | 3.8      | 3.7    | 4.2          | 4.5  |
| Screen                                | 4.3      | 4.5    | 3.1          | 4.7  |
| Accessories                           | 4.2      | 3.9    | 3.8          | 4.3  |

| **Categories deemed lowest importance** |          |        |              |      |
| Appearance                            | 4.0      | 3.8    | 3.7          | 4.1  |
| Size                                  | 4.1      | 3.8    | 4.2          | 4.4  |
| Capabilities                          | 4.0      | 2.0    | 1.0          | 4.0  |
| Info layout                           | 4.2      | 4.2    | 4.1          | 4.7  |
| Interface                             | 3.7      | 2.6    | 2.4          | 3.7  |

| **Total**                             | 54.9     | 50.4   | 46.0         | 56.3 |

MT10) selected the Earscan as easiest to use. Eight out of eight (2 ties with MT10) selected the Earscan as the most simple to obtain a good seal.

The features representing the main differences between the 4 tympanometers are listed on pages 951 and 952. Features are identified as positive or negative and ranked according to how they impacted the final selection from most influential to least.

### REFERENCES

### Features of 4 primary care tympanometers

#### EARSCAN

**Positive features**
- Easiest to use and obtain a seal
- Provides excellent feedback on little screen when “Testing” or “Blocked,” etc
- Offers Tympanometry, Acoustic Reflex Testing and Audiometry
- Performs Tympanometry followed by Acoustic Reflex Testing at one time
- Compatible with software integration
- Small pencil-like probe: fits in hand nicely and noninvasive appearance to patient
- Easy to view the ear-tip seal when performing the exam
- Excellent ear tips (cuffs) in terms of shape and malleability; affordable
- Probe tip easily disassembled and cleaned
- Low rate of reported mechanical problems
- Three-year warranty
- Control unit contained/packaged and protected
- No issue related to battery power
- No hinged parts and no separate portable parts
- Sealed buttons

**Easy to turn on with toggle switch**
- Monitor signals completion, “Remove Probe”
- Sound of air pump signals completion
- Best fit of calibration volume tube
- Also accepts GSI ear tips
- Popular in the field for occupational health
- Retail price $2595 with printer

**Negative features**
- Does not have the same kind of portability as a handheld device
- Buttons and screen commands can be confusing
- Glare on screen decreases viewing angle from 160° x 160° to 90° H and 150° V
- Cord/tubing from control unit to probe
- Little clear air tube may kink
- Requires 120 volts to function
- Instructional manual is only rated as fair
- Clearing data can be confusing
- Older appearance

#### MT10

**Positive features**
- Easy to use and obtain a seal
- Performs Tympanometry followed by Acoustic Reflex Testing at one time
- Offers Tympanometry, Expanded Tympanometry, Acoustic Reflex Testing, and Audiometry Screening
- Second smallest footprint if obtained without the printer
- Easy to view the ear-tip seal when performing the exam
- Controls are generally navigable once user is trained
- Can be programmed to make certain functions available
- Portability in a cable-free handheld device
- Looks sleek and modern
- Compatible with software integration
- Very good ear tips with multiple shapes
- Large screen and graph size
- Soft background color and high screen resolution
- Probe tip easily disassembled and cleaned
- Uses nonproprietary batteries (3 AA NiMH or NiCa batteries)
- Changing the batteries is simple
- Auto shutoff to save battery life
- Probe head removes for inserting into infant ears
- Turns on with pressing any button
- Stores multiple tests
- Very good volume calibration tool
- Retail price $2995 with printer

**Negative features**
- Large size can be difficult to manipulate, clumsy
- Large size can be intimidating to patient
- Provides subtle feedback on screen when “Open” or “Blocked,” etc; difficult to notice it because of other displayed data; busy screen
- Turning on the unit reveals prior saved data and performing test can replace data for one ear and leave old data in the other. Navigating options are confusing to some users
- Storing multiple tests (up to 20) may cause confusion or error if information is transferred by software
- User manual is rated as fair
- Glare decreases viewing angle from 160° x 160° to 90° x 90°
- Requires battery power

- Relies on contacts for power & data transfer
- Looks like a radar gun going into patient’s ear
- Can be dropped or knocked out of docking station
- Battery charging issues:
  - Before use, batteries require cycle of charge 3 hours, off for seconds, then charge 3 hours
  - It is recommended to discharge NiCa batteries totally at intervals of 2 to 3 weeks
  - Charging lamp is a little difficult to notice
  - Need to unplug the charger if you put non-rechargeable AA batteries in the unit
# Features of 4 primary care tympanometers (continued)

## Positive Features

- Easy to use and obtain a seal
- Easy to view the ear-tip seal when performing the exam
- Portability in a cable-free handheld device
- No glare on screen
- Best viewing angle 170° x 170°
- Excellent manual
- Very good ear tips
- Probe easily disassembled and cleaned
- Turns on when removed from docking station and press L or R
- Very good volume calibration tool
- Auto shutoff to save battery life
- Can use 9-volt alkaline battery if needed
- Changing this battery is only slightly difficult, with lead wires requiring positioning to close the unit
- Also accepts Earscan tips
- Popular among audiologists for mobile screening
- Retail price $2475 with printer

## Negative Features

- No software interface and no plans to develop an interface
- Displays confusing symbols as feedback when “Testing” or “Blocked,” etc
- Memory function is confusing and might lead to misidentified data
- Does not provide Acoustic Reflex Testing
- Relies on contacts for data transfer and power charging (on rare occasions, data did not transfer due to contact misalignment)
- Requires battery power and proprietary GSI battery recommended
- Storing multiple tests (up to 2 for each ear) may cause confusion or error in identifying data
- Somewhat unstable in docking station; dislodges slightly with Jolt test
- Looks like a drill going into patient’s ear
- Can be dropped or knocked out of docking station
- Slow printer
- Battery charging issues:
  - Longest life for battery if cycled from full charge to low charge to full charge
  - Sitting in charger all of the time reduces battery capacity somewhat
  - Full discharge requires 14 hours recharging to restore
- Charger should be unplugged if unused for >1 month

## GSI 37

- Familiar appearance to clinicians (resembles an otoscope)
- Provides excellent feedback on little screen when “Testing” or “Blocked,” etc
- Smallest footprint if obtained without the printer
- Portability in a cable-free handheld device
- Excellent manual
- Turns on by removing from docking station and press Test
- Has a tip ejector on the probe
- Auto shutoff to save battery life
- Prints the fastest
- Various options for printing data
- Commonly found in family practice clinics
- Retail price $2900 with printer

## MicroTymp 2

- Is confusing
- Will print a graph without the numerical data
- Small screen and graph size
- Glare on screen decreases viewing angle from 170° x 170° to 120° x 120°
- Poor ear tips
- Label the graph L or R after performing the exam
- Only unit that uses L or R from patient’s view
- Data retained can be mixed with new data
- Probe tip cannot be removed for cleaning
- Requires battery power and proprietary WA battery
- Relies on infrared for data transfer and contacts for charging
- Can be dropped or knocked out of docking station
- Battery charging issues:
  - Longest life for battery if cycled from full charge to low charge to full charge
  - Full discharge requires 14 hours recharging to restore
- Battery must be removed if the unit is out of the charger and unused for >1 month
- Changing this battery is moderately difficult