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# Table of Contents

- **Foreword** .................................................................................................................... i
- **Icon Key** .................................................................................................................. ii

## 3 Introduction to ECochG ................................................................. 1

## Clinical Applications ........................................................................ 2

## Patient Preparation ........................................................................ 3

  - **Choose an electrode** .............................................................................................. 3
    - **Tip-trode** .............................................................................................................. 4
    - **Tymptrode** ......................................................................................................... 6
  - **Prepare the patient** ............................................................................................... 8
    - Instruct patient on test procedures ........................................................................ 9
    - Select an electrode montage ................................................................................ 11
    - Place skin electrodes ............................................................................................. 13
    - Place ear electrodes (Tip-trodes and/or Tymptrodes) ........................................... 14
    - Connect montage electrodes ............................................................................... 15
Test Procedures

Select a protocol
Select parameters

Step-by-Step Instructions

Tip-trode instructions
Tymptrode instructions

Results and Interpretations

Identify waveforms
Reference normative data

SP/AP Ratios
Foreword

*Auditory Evoked Potentials* provides an overview of the uses of Evoked Potential (EP) testing and is intended for anyone interested in learning more about EP. Each chapter in the book will be issued as a separate document and will be available in printed and online formats.

The chapters are:

- Chapter 1 Introduction to EP
- Chapter 2 Pediatric Protocols
- Chapter 3 Electrocochleography (ECochG)
- Chapter 4 Special EP tests
- Chapter 5 ASSR

This book was developed by ICS Medical in response to requests for additional information that will enhance the operator’s ability to use its CHARTR with PediABR EP testing equipment. This system enables operators to conduct EP tests using standard test protocols, or to customize the protocols to accommodate specific testing and facility requirements.

Additional copies of this book may be obtained online at www.icsmedical.com or from ICS Medical customer service.
## Icon Key

These icons are used consistently throughout *Auditory Evoked Potentials*.

<table>
<thead>
<tr>
<th>icon</th>
<th>key</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>📊</td>
<td>Clinical Applications</td>
<td>Provides information on the indications and appropriate applications for a test or series of tests.</td>
</tr>
<tr>
<td>🔍</td>
<td>Patient Preparation</td>
<td>Contains information and instructions on preparing patients for testing.</td>
</tr>
<tr>
<td>📃</td>
<td>Test Procedures</td>
<td>Contains information and instructions on conducting specific tests.</td>
</tr>
<tr>
<td>📈</td>
<td>Results and Interpretations</td>
<td>Provides information and instructions on how to interpret and analyze test results.</td>
</tr>
<tr>
<td>📚</td>
<td>Notes</td>
<td>Provides additional information and clarifications.</td>
</tr>
<tr>
<td>📝</td>
<td>Tips</td>
<td>Provides hints, suggestions, and alternate ways to use or apply the information.</td>
</tr>
</tbody>
</table>
Introduction to ECochG

Electrocochleography (ECochG) is an ABR protocol where the electrode is placed as close to the tympanic membrane or the cochlea as is realistic depending on the type of electrode and the skill and training of the professional placing the electrode. The ECochG stimulus is a click or tone burst presented at a relatively slow rate (11.1/sec). The response is collected from 0 to 5 msecs. The test is used to identify Ménière’s disease, particularly hydrops, and for other applications.

The components of ECochG are:

- **CM (cochlear microphonic)**
  a stimulus-dependent cochlear response, which changes direction with changing polarity. Hence, it is not detected when averaging is performed to alternating polarity.

- **SP (summating potential)**
  direct current response from the Organ of Corti hair cells. SP is often seen as a leading hump on the AP or wave I, although sometimes it can appear as a separate hump.

- **AP (action potential)**
  alternating current response generated by the cochlear end of the 8th nerve (wave I). The AP represents the summed response of thousands of firing auditory nerve fibers.
Clinical Applications

ECochG testing is used to:

- Identify and monitor Ménière’s disease
- Enhance ABR wave I for identification of the Wave I-V interval
- Monitor cochlear function during surgical procedures

An ECochG test is indicated for a patient who complains of:

- Unilateral hearing loss
- Buzzing or fullness sensation in the ear
- Balance difficulties
- When there is a suspicion of acoustic neuroma
Patient Preparation

The patient preparation information in this section applies to all patients, regardless of age or circumstances. The operator may need to make specific accommodations depending on the patient status and the test environment.

This section provides information on how to:

- Choose an electrode for placement on a patient
- Prepare a patient for testing

Choose an electrode

Three types of electrodes are used for ECochG testing:

- **Ear-canal**
  also referred to as a tip-trode (gold foil), has a foil covered foam insert piece that is placed in the external ear canal but does not touch the eardrum.

- **Extra tympanic**
  also referred to as a tymptrode (TM), has a thin coated wire that is placed in the ear canal and rests gently on the eardrum.

- **Transtympanic**
  also referred to as a needle electrode, is placed through the tympanic membrane and rests on the oval window. A physician must place this type of electrode.
**Tip-trode**

The tip-trode is an ear canal electrode. It is made of foam that is wrapped with a thin gold film. After the ear is prepared, the tip-trode is gently squeezed and then placed in the ear canal, where it will expand and snugly seal the ear.

Two outputs:
- Connect long cable with plug to a port on patient cable
- Connect short cable to the ER-3A insert phone transducer box

Compression fitting, squeeze to insert end of tip-trode

Insert into cable fitting

Place tip-trode in ear

Tip-trode with left (blue) and right (red) ear cables

Cable jacks plug into ports on patient cable
A double cable is used to connect the tip-trode to the patient cable with a safety plug (DIN Touch Proof Female Safety Jacks). The other end of the tip-trode cable connects to an ER-3A insert phone transducer box to allow the transmission of the auditory stimulus into the ear canal.

Note: The operator must remember to replace the red and blue tubing from the Tip-trode Y-cable with the red and blue tubing from the insert phones. Do not connect the two tubing lengths together.
Tymptrode

A tymptrode is an extra tympanic electrode. It consists of a thin wire shielded with a protective plastic coating. The tymptrode is placed in the ear canal next to the ear drum.

Put conductive gel on the tip of the tymptrode before inserting it into the ear canal. The tymptrode is led into the ear canal until it reaches the eardrum. When placed properly, the tymptrode rests gently on the eardrum, and the gel assists in making contact with the eardrum.

*Note:* A tymptrode is contraindicated in patients with perforated eardrums.
The tymptrode cable connects to a Y-cable that plugs into the patient cable through typical safety plug (DIN Touch Proof Female Safety Jacks). An insert earphone, placed a short distance into the ear canal, provides the sound stimulus.

The forehead ground electrode plugs into the ground jumper on the Y-cable for safety.
Prepare the patient

Proper patient preparation for ECoChG testing includes these steps:

- Instruct patient on test procedures
- Select an electrode montage
- Place skin electrodes
- Place ear electrodes
- Connect montage electrodes

You will need some or all of these items to prepare the patient for testing:

- Electrodes – tip-trodes, tymptrodes, disposable electrodes
- ER-3 insert phones
- ICS patient cable
- Insert phone tubing
- Jumper
- Prep-paste
- Conductive gel
- Adhesive tape
**Instruct patient on test procedures**

The following information may be helpful in explaining the test procedure to your patient.

ECochG is a simple test with little discomfort. On average the test will take 30 minutes to perform.

*Note:* Electrocochleography (ECochG) is an objective test for endolymphatic hydrops. Ménière’s disease is the most common cause of endolymphatic hydrops.

Before the test, electrodes will be placed on the forehead and in the ear canal. Two electrodes will be placed in the ears near the eardrum. These electrodes collect auditory evoked responses. The electrode on the forehead acts as a ground.

*Note:* Some physicians may perform the test using a transtympanic electrode, a fine needle that is passed through eardrum. The procedure offers little discomfort.

During the test, a sound stimulus will be introduced. A click sound stimulus will be presented through headphones or an insert phone (a soft foam ear tip that is also placed in the ear canal). Throughout the test, the click sounds will be sent to the ear at varying intensities. The sounds may be relatively loud, but they should never be uncomfortable.

*Note:* Sometimes the ear canal electrodes and the sound source foam tip are combined into one piece for easier application.
Before beginning the test, ask the patient to lie back (on a table or adjustable chair), close his/her eyes, relax, and remain as still as possible. Turn off the room lights.

During the test, the CHARTR EP system sends about 1000 to 2000 clicks to an ear for each test run and records the activity for 5 milliseconds after each click. The system records and averages each response. At the end of a test run, the system analyzes the test data and presents the results in a report.
Select an electrode montage

Select an ECochG electrode montage based on the protocol to be used for testing. Three examples are shown. Each electrode montage must be properly connected to the patient cable and to a stimulus device, such as an insert phone.

<table>
<thead>
<tr>
<th>Single channel montage tip-trode (left or right ear)</th>
<th>ECochG/ABR montage (left or right ear)</th>
<th>Single channel montage tymptrode (left ear)</th>
</tr>
</thead>
</table>
| This montage uses 3 electrodes and one channel. It provides an ipsilateral ECochG only.  
Left ear – tip-trode  
Right ear – tip-trode  
Forehead – ground electrode | This montage requires 4 electrodes and 2 channels. One channel collects an ABR and the other channel collects an ECochG with the peak pointing up like the ABR.  
Left ear – tip-trode  
Right ear – tip-trode  
High forehead – disposable or reusable electrode  
Low forehead – ground electrode | This montage requires 3 electrodes and 2 channels. One channel collects an ABR and the other channel collects an ECochG with the peak pointing down (opposite the ABR).  
Left ear – tymptrode & insert phone  
Right mastoid – electrode  
Forehead – ground electrode |

**Tip:** To reverse polarity on any test, change or switch the (+) and (-) electrodes. This will cause the peak to point down.
The single channel ECochG is the only montage that uses three electrodes—one traditional EP electrode on the forehead, which acts as the ground, and two tip-trode electrodes, one in each ear canal.

**Note:** Sometimes when using tymptrodes, audiologists prefer to reuse one electrode for both ears on the same patient. If this is done, then a traditional electrode needs to be placed on the mastoid or earlobe of the non-test ear.

Four electrodes are used for a two channel combined ABR/ECochG montage—one on the high forehead or vertex electrode (active ABR electrode), one on the low forehead ground electrode, and two mastoid electrodes (as references). You will also need two tip-trodes or one tymptrode for this montage.
**Place skin electrodes**

Typically, skin electrodes are applied to the upper and lower forehead and over the mastoid bone behind the ear.

To apply an electrode to the skin:

1. Clean electrode skin sites with an alcohol wipe.
2. Abrade skin with a mild abrasive solution such as NU-Prep. Wipe off any excess solution.
3. Apply electrode paste to reusable electrodes. Disposable electrodes are ready to apply on prepared skin.
4. Apply the electrodes and secure with tape, if needed.

**Note:** See *Test Procedures* for detailed instructions on how to place and connect electrodes and conduct a test.
Place ear electrodes (tip-trodes and/or tymptrodes)

1. Check both ear canals to make sure they are clean and unobstructed.
2. Place the tip-trode or tymptrode in the ear canal. See Tip-trode instructions and/or Tymptrode instructions.

3. Connect the electrodes to the connecting cable. Then connect the connecting cable from the electrode to the patient cable. See Connect montage electrodes.

Note: See Tip-trode, Tymptrode, Select an Electrode Montage, and Connect Montage Electrodes for more information.
**Connect montage electrodes**

Connect the montage electrode leads to the patient cable. Six protocols and the associated patient cable connections are shown below.

<table>
<thead>
<tr>
<th>Protocol: Single channel, both ears ECochG</th>
<th>Protocol: Single channel, single ear (right ear)</th>
<th>Protocol: Single channel, single ear (left ear)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connect:</td>
<td>Connect:</td>
<td>Connect:</td>
</tr>
<tr>
<td>Left ear electrode to Ch 1 Ref (−)</td>
<td>Right ear electrode [stimulated] to Ch 2 Ref (−)</td>
<td>Left ear electrode [stimulated] to Ch 1 Ref (−)</td>
</tr>
<tr>
<td>Right ear electrode to Ch 1 Act (+)</td>
<td>Left ear electrode to Ch 2 Act (+)</td>
<td>Right ear electrode to Ch 1 Act (+)</td>
</tr>
<tr>
<td>Forehead to Ground</td>
<td>Forehead to Ground</td>
<td>Forehead to Ground</td>
</tr>
<tr>
<td>Jumper: 2 jumpers required</td>
<td>Jumper: None</td>
<td>Jumper: None</td>
</tr>
<tr>
<td>Ch 1 + and Ch 2 −</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ch 1 − and Ch 2 +</td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------------------------------------</td>
<td>-----------------------------------------------------------</td>
<td>-----------------------------------------------------------</td>
</tr>
<tr>
<td>Channel 1 is left ear ABR</td>
<td>Connect: Left electrode [stimulated] to Ch 1 Ref (−)</td>
<td>Connect: Left electrode to Ch 2 Ref (−)</td>
</tr>
<tr>
<td>Channel 2 is right ear ECochG</td>
<td>Note: this electrode is jumped with the port for Ch 2 Act (+) to allow for a horizontal ECochG test</td>
<td>Right electrode to Ch 1 Ref (+)</td>
</tr>
<tr>
<td></td>
<td>Right electrode to Ch 2 Ref (−)</td>
<td>Forehead to ground</td>
</tr>
<tr>
<td></td>
<td>High forehead [vertex] to Ch 1 Act (+)</td>
<td>Jumper: None</td>
</tr>
<tr>
<td></td>
<td>Forehead to Ground</td>
<td>This electrode plugs into the green jumper included with the kit. The green jumper plugs into the GND (ground) port on the patient cable.</td>
</tr>
<tr>
<td></td>
<td>Jumper: Ch 1− and Ch 2+</td>
<td>Jumper: None</td>
</tr>
<tr>
<td></td>
<td></td>
<td>This electrode plugs into the green jumper included with the kit. The green jumper plugs into the GND (ground) port on the patient cable.</td>
</tr>
</tbody>
</table>
Test Procedures

♦ Select a protocol
♦ Select parameters
♦ Step-by-step instructions
♦ Tip-trode instructions
♦ Tymptrode instructions

Select a protocol

In the CHARTR EP program, the ECoChG procedure has an 80 dB protocol for the left ear. The instructions in this chapter use the default ECoChG as a starting point.

To access the default ECoChG protocol on the New Test tab, locate the ECoChG procedure and select the 80 dB ECoChG protocol.

Note: Your clinic may have modified these ECoChG protocols to meet specific requirements. If that is the case, the names of the protocols and the parameter settings may vary from those discussed and/or shown in this chapter.
Select parameters

The CHARTR EP ECoChG default protocol automatically selects the appropriate trial parameter settings for collecting a typical ECoChG. To view the parameter settings, click **F5 Trial Settings** to display the Edit Protocol ECoChG dialog.

![Edit Protocol ECoChG dialog](image)

**Tips:**
- Using an alternating stimulus will eliminate the cochlear microphonic.
- A condensation click will display the cochlear microphonic with exactly opposite polarity than will a rarefaction.
- A very fast click (e.g., 99 clicks/sec) rate will eliminate the AP, but the SP will remain intact.

**Note:** It is a good idea to create your own individual protocols for each ear and save them as ECoChG left and ECoChG right. Then while testing, you can select the protocol for the specific ear without having to make trial setting changes between the tests for each ear. To learn how to make your own protocols, see “Defining Your own Protocols” in the CHARTR EP Operator’s Manual.
Step-by-step instructions

This section contains two sets of instructions for collecting ECochG data—one using tip-trodes (gold foil) and one using tymptrodes.

Tip-trode instructions

These instructions will help you connect electrodes to the patient and patient cable using tip-trodes and collect ECochG data from the left and right ears (starting with the left ear).

1. Open CHARTR EP and select the default protocol for ECochG.
   a. Click F5 Trial Settings to display the Trial Settings dialog.
   b. Make sure the left stimulus is selected on and the right stimulus is off.
   c. Make sure Channel 1 is selected on and Channel 2 is off.
   d. Click OK to accept the settings and close the dialog and return to the Main Window.

2. Prepare the tip-trodes (gold foil) electrodes.
   a. Remove the blue and red tubing from the standard ER-3 insert phones and replace it with the blue and red tubing that is attached to the ECochG leads (the leads have two pieces; tubing and a pinch connector for the gold tip).
   b. Slide a tip-trode into the middle of the pincher on the lead and gently press the pincher closed to assure a tight connection.
3. **Apply the electrodes to the patient.**
   a. Place a tip-trode in both ears.
   b. Or, place a reusable or disposable electrode behind both ears and place one tip-trode in the test ear only (this saves on costs if only testing one ear).

4. **Connect the electrodes to the patient cable.**
   a. Plug the left ECochG lead wire into the Channel 1 Ref (–) port on the patient cable (blue).
   b. Plug the right ECochG lead into the Channel 1 Act (+) port on the patient cable (yellow).
   c. Plug the low forehead snap-on or disposable lead wire into the ground port on the patient cable.

**Note:** When testing the left ear, the tip-trode in the left ear is the reference (–) channel and the opposite (right) mastoid is the active (+) channel. The right mastoid electrode is plugged into Channel 1 + (yellow) port on the patient cable.

**Tip:** Sometimes it is helpful to apply a light coating of conductive paste on the gold foil tip before inserting it into the ear. This will improve impedances and less artifact will be present in the tracings.
5. **Click F12 Average to begin collecting.** Each tracing will be labeled LIxx (left ipsilateral 80 dB. See the *CHARTR EP Operator’s Manual* for further assistance in labeling waveforms). It is recommended that you collect at least two runs per ear.

6. **Collect data from the right ear.**
   a. Remove the tip-trode from the left ear and place it into the right ear (unless two tip-trodes were placed before collecting data).
   b. Plug the lead from the left ear into Channel 2 Act (+) (white) on the patient cable.
   c. Plug the lead from the right ear into Channel 2 Ref (–) (red) on the patient cable.

7. **Click F5 Trial Settings.**
   a. Turn the right stimulus on and the left stimulus off.
   b. Turn Channel 2 on and Channel 1 off.

   ![Note: The right ear is now the reference (-) and the lead is plugged into the red port in the patient cable and the opposite mastoid (left mastoid) is active and the lead plugs into the white port.]

   c. Click OK to accept the settings and return to the Main Window.

8. **Click F12 Average to begin collecting.** Each tracing will be labeled RIxx. It is recommended that you collect at least two runs per ear.
Tymptrode instructions

To use a tymptrode to collect ECochG data:

1. **Select the default protocol for ECochG.**
   a. Click **F5 Trial Settings** to display the Trial Settings dialog.
   b. Make sure the left stimulus is selected on and the right stimulus is off.
   c. Make sure Channel 1 is selected on and Channel 2 is off.
   d. Click **OK** to accept the settings and return to the Main Window.

2. **Apply the electrodes.**
   a. Gently wipe the external ear canal with prep paste.
   b. Apply a dab of conductive gel to the tip of the tymptrode.
   c. Place the tymptrode at the left eardrum and tape the lead to the patient’s cheek.
   d. Gently place a beige insert phone tip into the same ear canal.
   e. Place a snap-on or disposable electrode behind the right ear.
   f. Place a snap-on or disposable electrode on the low forehead.
3. **Connect the electrodes to the patient cable.**
   a. Plug the tymptrode into the Channel 1 Ref (–) port (blue) on the patient cable.
   b. Plug the right ear/mastoid electrode into the Channel 1 Act (+) port (yellow) on the patient cable.
   c. Plug the low forehead snap-on or disposable lead into the supplied green jumper.
   d. Plug the green jumper into the ground port (black) on the patient cable.

4. **Click F12 Average to begin collecting.** Each tracing will be labeled LIxx. It is recommended that you collect at least two runs per ear.

5. **Collect data from the right ear.**
   a. Remove the tymptrode from the left ear and place it in the right ear next to the eardrum. Tape the wire lead to the patient’s cheek.
   b. Gently place a beige insert phone tip into the right ear canal.
   c. Place a regular snap-on or disposable electrode behind the left ear.
   d. Place a snap-on or disposable electrode on the low forehead (ground).

6. **Connect the electrodes to the patient cable.**
   a. Plug the tymptrode from the right ear into the Channel 2 Ref (–) port (red) on the patient cable.
   b. Plug the left ear/mastoid electrode into the Channel 2 Act (+) port (white) on the patient cable.
c. Plug the low forehead snap-on or disposable lead into the supplied green jumper and then place the green jumper in the ground port (black) on the patient cable.

7. **Click F5 Trials Settings.**
   a. Select the right ear stimulus on and the left ear off.
   b. Turn Channel 2 on and Channel 1 off.
   c. Click **OK** to accept the settings and return to the Main Window.

8. **Click F12 Average and begin collecting.** Each tracing will be labeled RIxx. It is recommended that you collect at least two runs per ear.
Results and Interpretations

- Identify waveforms
- Reference normative data

Identify waveforms

Three essential markers used in ECochG:

- **BL** – baseline
- **SP** – summating potential
- **AP** – action potential

Some people choose to mark the remaining standard ABR waveforms (II, III, and V) that are showing also. Once the markers are placed, you can observe the latency of each point marked, which is the time between 0.0 msec and the marker or you can observe the amplitude of each marked point which is the height in uv from the baseline point to SP and AP. Most people use the amplitude measure for assessing pathology.
Reference normative data

The most frequently used measure for interpreting ECochG waveforms is the ratio of the height of SP versus AP; SP/AP x 100. This number is expressed as a percentage. The CHARTER EP software will automatically compute this number once you have completed labeling the waveforms. The number displays in the calculations box along with additional latency and amplitude calculations.

Data collection results (waveforms marked by operator; waveform 10 selected)

Waveform 10 data in the Calculation box (located below and to the left of the waveform area)
Normative data for ECochG differs depending on the electrode used for data collection—tip-trode (gold foil) or tymptrode. Commonly accepted norms use cut-off percentages of 25% for the tymptrode and 50% for a gold foil electrode. This means a percentage greater than 25% is a significant finding when using a tymptrode and a percentage greater than 50% is significant when using a gold foil electrode.

Gold foil electrodes are placed in the outer ear canal further away from the source of the signal and hence are less sensitive. Therefore, wider variations in responses are seen and a higher percentage difference is necessary to call a result abnormal.

Normal ears have a larger difference between the amplitudes of SP and AP and diseased ears have a small amplitude difference between SP and AP. Therefore, larger ratios may indicate pathology and often can be seen in patients with Ménière's disease.
SP/AP Ratios

A large SP/AP ratio is typically indicative of a pathological condition.

![Diagram showing normal and abnormal SP/AP ratios](image-url)