Evidence-Based Audiologic Management of Bacterial Meningitis:

Clinical Pathways and Outcomes

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Children's Hospital of Philadelphia
Center for Childhood Communication

Learning Objectives

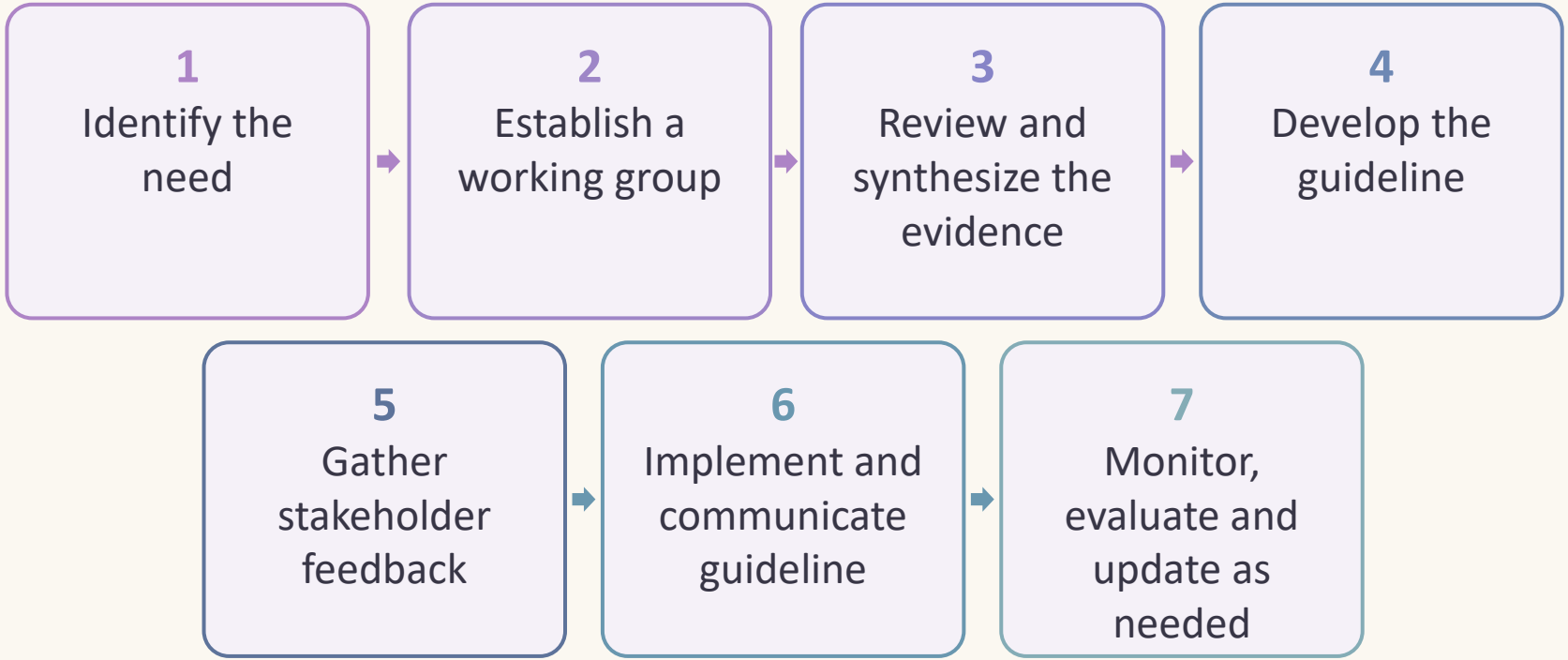
- Recognize how evidence-based practice guidelines (EBPG) can support consistent, timely and patient-centered care for specific populations
- Describe the relationship between bacterial meningitis and hearing loss including the importance of timely follow-up
- Apply evidence-based guideline for audiologic management following bacterial meningitis

What is an EBPG?

- Clear recommendations that translate peer-reviewed research and clinical experience into consistent care
- A shared standard for assessing and managing patients, with room to adapt to individual circumstances
- Living documents, revised as the evidence evolves

Fraile Navarro et al., 2023; APA, 2024

Developing an EBPG



The Need for a Meningitis EBPG



Audiology could be consulted sooner



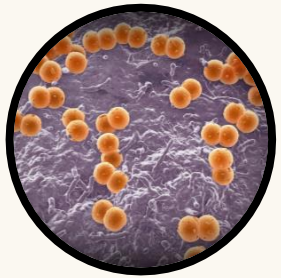
Smoother handoff from inpatient care to outpatient management



Cochlear implant evaluation and surgery may need to be expedited

Why Did We Need an EBPG?

- Lacked a standardized, evidence-supported approach
- Resulted in inconsistent clinical care between providers
- Debates could delay appropriate treatment
- Questionable quality of care



What is Meningitis?

- Inflammation of the lining of the brain and spinal cord
- Affects the fluid and membranes (meninges) around the brain and spinal cord
- Common bacteria and pathogens
    - Streptococcus pneumoniae
    - Neisseria meningitis
    - Haemophilus influenzae type B

Viral vs. Bacterial Meningitis

Viral Meningitis

- Most common form of meningitis
- Usually caused by non-polio enteroviruses; peaks in summer and fall
- Often milder — most people recover fully in 7–10 days
- No specific treatment in most cases; supportive care
- Can still be serious in infants and immunocompromised patients

Bacterial Meningitis

- Far less common, but much more severe
- S. pneumoniae, N. meningitidis, Hib, group B Strep, Listeria
- A medical emergency — can become life-threatening within hours
- Requires immediate antibiotics and hospitalization
- Survivors may have lasting effects, including hearing loss

CDC, 2025

Possible Signs of Meningitis

Early recognition and urgent evaluation are critical.

HIGH FEVER
Sudden onset of high fever (>38.5°C / 101.3°F)



HEADACHE
Severe or worsening headache, often rapid in onset



STIFF NECK
Neck stiffness or pain with forward flexion



NAUSEA
Persistent nausea or feeling unwell



VOMITING
Repeated vomiting (may be projectile)



- Not explained by other illness
- May occur early
- May continue as condition worsens

PHOTOPHOBIA
Sensitivity to light



- Discomfort in bright light
- May prefer dark environments
- Common in meningitis

ALTERED MENTAL STATUS
Confusion, drowsiness, difficulty arousing, or behavioral change



- Confusion
- Irritability
- Drowsiness
- Difficulty responding

MENINGITIS CAN PROGRESS RAPIDLY.
Trust your clinical judgment.

SEEK IMMEDIATE MEDICAL CARE.
Do not delay evaluation or treatment.



Sources: CDC. Meningitis (Bacterial) Clinical Signs and Symptoms. 2024.
Nigrovic LE, et al. Clinical Practice Guideline: The Diagnosis and Management of Acute Bacterial Meningitis in Infants and Children. *Pediatrics*. 2021.

CDC, 2025

Symptoms in Babies

- Babies may not have the classic symptoms, and signs can be hard to notice
- Symptoms include:
    - Inactivity or fatigue
    - Irritability
    - Poor feeding
    - Bulging anterior fontanelle (the soft spot of the skull)
    - Abnormal reflexes
    - Emesis

Meningitis Vaccine

- November 1999: Meningococcal C vaccine introduced
- From 1999-2018: overall pneumococcal disease rates among children under 5 years old decreased by 93%



Meningitis and Hearing Loss: Pathophysiology



- Inflammation may extend into the inner ear
  - Spreads through cochlear aqueduct and internal auditory canal
- Cochlear damage can be rapid and permanent
  - Inflammation & bacteria damage hair cells & supporting structures
- Ossification may follow inflammation
  - Severe inflammation of cochlea can trigger new bone formation (labyrinthitis ossificans)

A Leading Risk Factor for Childhood Hearing Loss

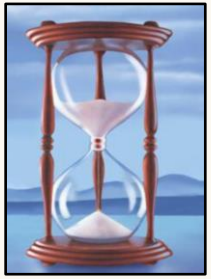
The Joint Committee on Infant Hearing lists confirmed bacterial and/or viral meningitis as a risk factor for childhood hearing loss (JCIH, 2019)

- Hearing loss is frequently bilateral and severe to profound
- Early audiologic consultation is the only reliable way to detect loss within the treatment window

11%

mean incidence of hearing loss following bacterial meningitis (range 2–35%)

Rodenburg-Vlot et al., 2016

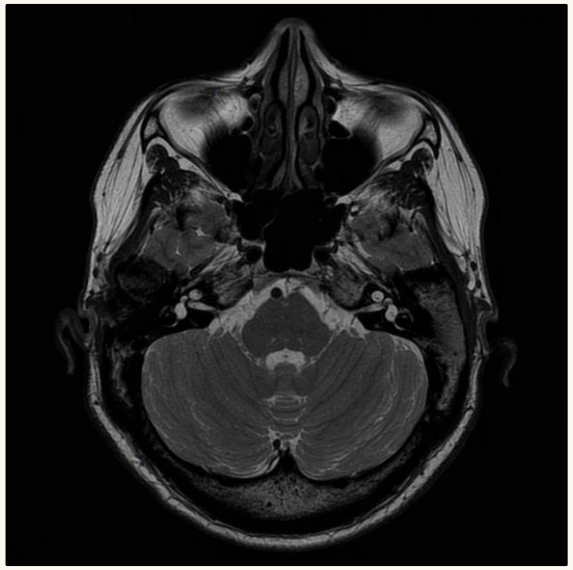


Ossification Potential

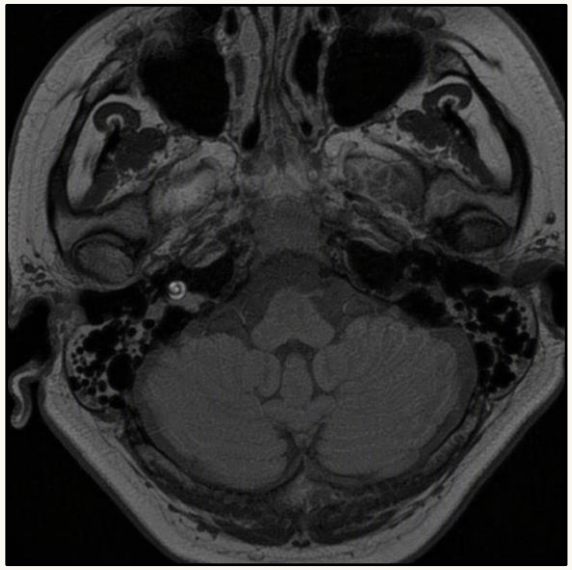
Infection	Labyrinthitis	Ossification	Implant risk
Bacterial meningitis reaches the inner ear	Inflammation of the cochlea begins	New bone can form within 4 weeks	Electrode insertion and outcomes are affected

Cochlear ossification can be rapid, occurring within four weeks of infection, and can compromise successful insertion of the cochlear implant electrode array (Durisin, 2010).

MRI Differences with Ossification



Normal cochlea:
patent fluid signal



Ossified cochlea:
loss of fluid signal

Why is this an Audiologic Emergency?

Hearing loss can develop rapidly

Cochlear injury may occur during acute phase and then progress over days and weeks

Hearing loss may not be apparent

Patients may be too sick, too young, sedated or neurologically impaired to show or report change in hearing

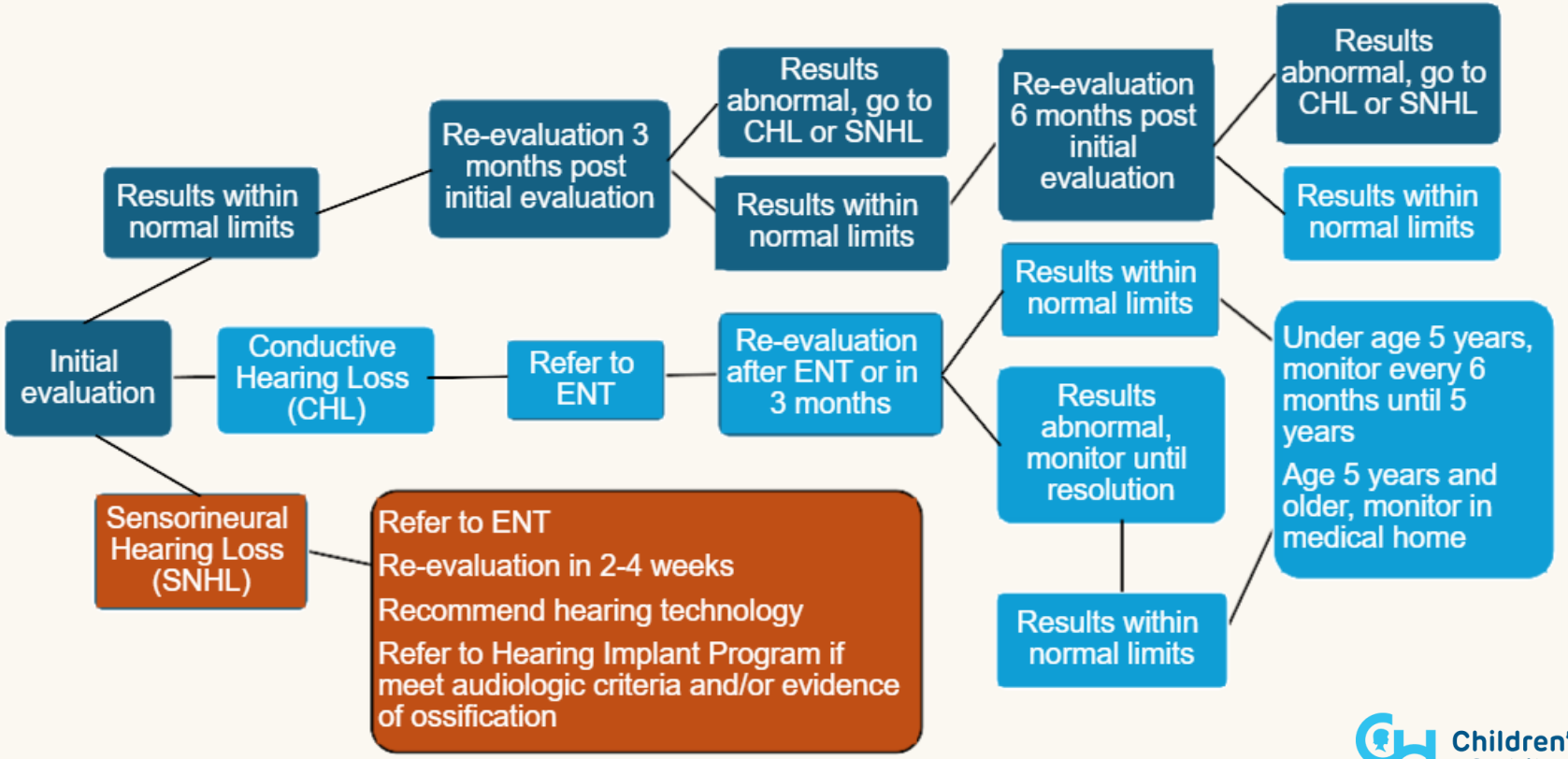
Early hearing assessment is critical

Audiologic evaluation should be done as soon as patient is medically stable with timely monitoring

Time is critical for intervention

Progressive cochlear injury can lead to ossification – limiting intervention options

Bacterial Meningitis Audiologic Surveillance



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Outcomes of This Guideline

- Standardizes rapid identification and management of hearing loss
- Ensures timely ABR testing and repeat ABR testing as needed
- Prompts early MRI to assess cochlear anatomy and presence or absence of cochlear ossification
- Expedites CI referrals when indicated



Case Study 1



Hospital admission

- 9-month-old admitted to CHOP with lethargy and a bulging fontanelle
- Born at 26 weeks gestation with a several-month NICU stay; passed newborn hearing screening in both ears
- Admitted to the PICU; total hospital stay of five weeks
- Audiology consult placed three weeks into the hospital stay
- Bilateral profound sensorineural hearing loss diagnosed
- MRI of the internal auditory canals ordered and within normal limits

Audiologic Timeline and Outcome

Timepoint	Event
Week 3	Audiology consult placed; bilateral profound sensorineural hearing loss diagnosed
Week 3	MRI of the internal auditory canals ordered; findings within normal limits
Week 5	Discharged to outpatient management; bilateral hearing aid fitting completed
+3 months	Repeat MRI of the internal auditory canals stable; MRI surveillance discontinued
+9 months	Seen by ENT; repeat MRI shows significant cochlear ossification
Outcome	Left ear could not be implanted; right cochlear implant partially inserted and the patient is now a non-user

Case Study 2



Purpose



Review the case

- Infant with pneumococcal meningitis at 4 months, from admission through bilateral cochlear implantation



Illustrate the guideline

- How the guideline shaped assessment and referrals



Demonstrate coordinated care

- Collaboration across Audiology, SLP, ENT, Neurology, Infectious Disease, and Intensive Care

CHOP's EBPG served as the primary framework for this work.

Inpatient Audiologic Timeline

Day	Event
13	Profound sensorineural hearing loss in both ears, patent PE tubes noted; referral to Cochlear Implant Team
18	Expedited Cochlear Implant Team evaluations completed by Otolaryngology, Audiology, Speech-Language Pathology, and Clinical Social Work
20	Second MRI with evidence of ongoing bilateral labyrinthitis ossificans, L>R; right shunt revised
25	Second ABR: profound sensorineural hearing loss in both ears, patent PE tubes noted
39	Bilateral cochlear implantation
40	Patient discharged

Coordinated, multidisciplinary care

Audiology	Otolaryngology	Speech-Language Pathology	Neurology
Infectious Disease	Intensive Care	Clinical Social Work	Cochlear Implant Team

Audiology collaborated on the development of the CHOP clinical care pathway for suspected meningitis in patients above 56 days — spanning the Emergency Department, inpatient units, and the ICU

Emergency Department, Inpatient and ICU Clinical Pathway

- Children with suspected meningitis, age greater than 56 days
- Spans ED triage, inpatient units, and the ICU through discharge planning
- Posted December 2017; last revised June 2026
- Authored across disciplines
  - *Infectious Diseases, Critical Care, Neurology, Emergency Medicine, Pharmacy, and Audiology*
- Includes goals and metrics, patient education, and provider resources
  - *Linked to the Febrile Young Infant, Sepsis, Status Epilepticus, and VP Shunt Obstruction/Infection pathways*

Pathway in Practice: Key Steps

Stage	What the pathway specifies
ED Triage	Initiate contact and droplet precautions at triage
Team Assessment	History and physical for signs suggesting acute bacterial meningitis; IV access and recommended labs; LMX cream to the lower back; NPO status for LP and imaging; sepsis huddle as clinically indicated
Lumbar Puncture	Review contraindications before LP; perform LP and send CSF studies If LP is contraindicated or CSF cannot be obtained, start antibiotics and perform LP when able; consider image-guided LP
CSF Interpretation	Compare results against typical CSF parameters; if findings are not consistent with bacterial meningitis, consider focal infection, epidural or subdural empyema or abscess, HSV or enteroviral meningoencephalitis, or autoimmune encephalitis
Antibiotics and Dexamethasone	Start antibiotics; add dexamethasone for high suspicion: severe illness with neurologic symptoms, CSF WBC greater than 500 with neutrophils above 50%, or a gram stain showing pleomorphic gram-negative rods or gram-positive cocci in pairs or chains
Inpatient Management	General management, consults, vascular access, and definitive therapy; chemoprophylaxis for contacts of proven Neisseria meningitidis or Haemophilus influenzae b; discharge planning with consultant follow-up

Where Audiology Sits in the Pathway

- Audiology is named among the pathway's authors and in its inpatient consults
- The dexamethasone decision at the antibiotic step is a hearing-preservation decision
- Roughly one in ten survivors has sensorineural loss, often bilateral and severe to profound
- Evaluation is requested once the child is medically stable, during inpatient management
  - *ABR for infants, with tympanometry and OAEs as adjuncts to rule out middle ear effusion*
- Profound loss or early ossification triggers immediate otolaryngology and cochlear implant referral
  - *Discharge planning carries consultant follow-up and surveillance for delayed or progressive loss*

Clinical Reflections

- Audiologic management of bacterial meningitis requires timely evaluation and appropriate monitoring within the context of overall medical management
- For pediatric patients with evidence of hearing loss, complex audiologic information must be conveyed to caregivers to support time-sensitive decision-making
- Rapid action by the clinical team is crucial to the patient's communication, educational, and quality-of-life outcomes



Summary

- Bacterial meningitis can cause rapid, permanent hearing loss
  - *Timely audiologic management is essential*
- EBPGs provide a clear consistent approach
- Clinical Pathways support timely coordinated care
  - *Who, when, what and what's next*
- Standardized care can improve consistency and outcomes
  - *Valuable for all clinical practice but especially for high-risk populations*

Thank you!

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Selected References

Scan for the clinical pathway

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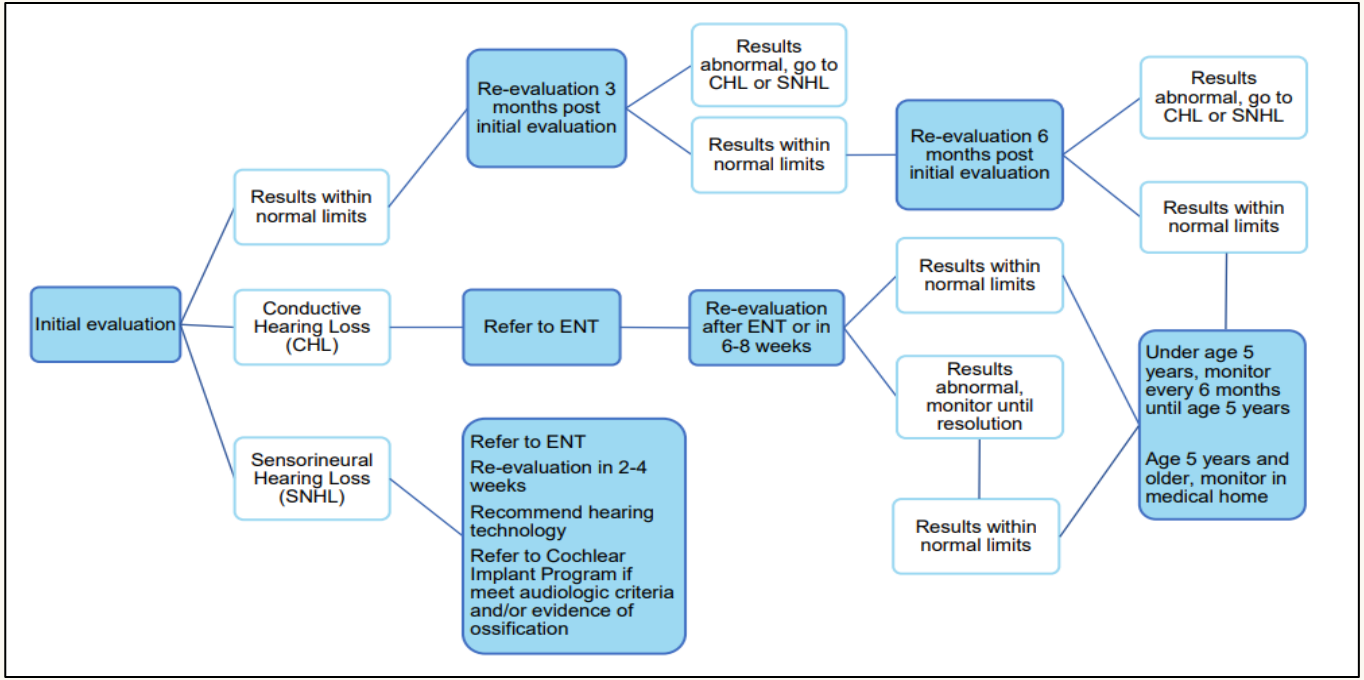
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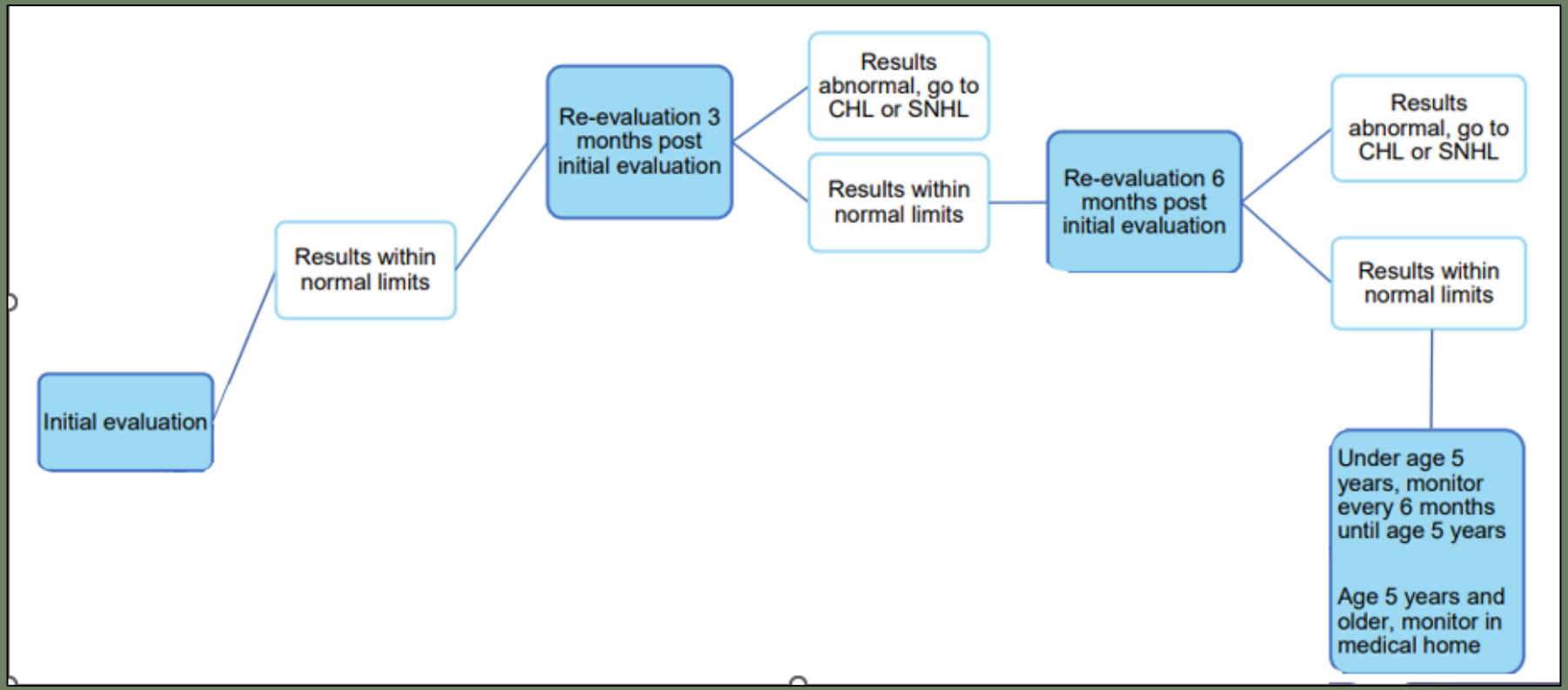
Key Takeaways

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  - *Timely audiologic management is essential*
- EBPGs provide a clear consistent approach
- Clinical Pathways support timely coordinated care
  - *Who, when, what and what's next*
- Standardized care can improve consistency and outcomes
  - *Valuable for all clinical practice but especially for high-risk populations*

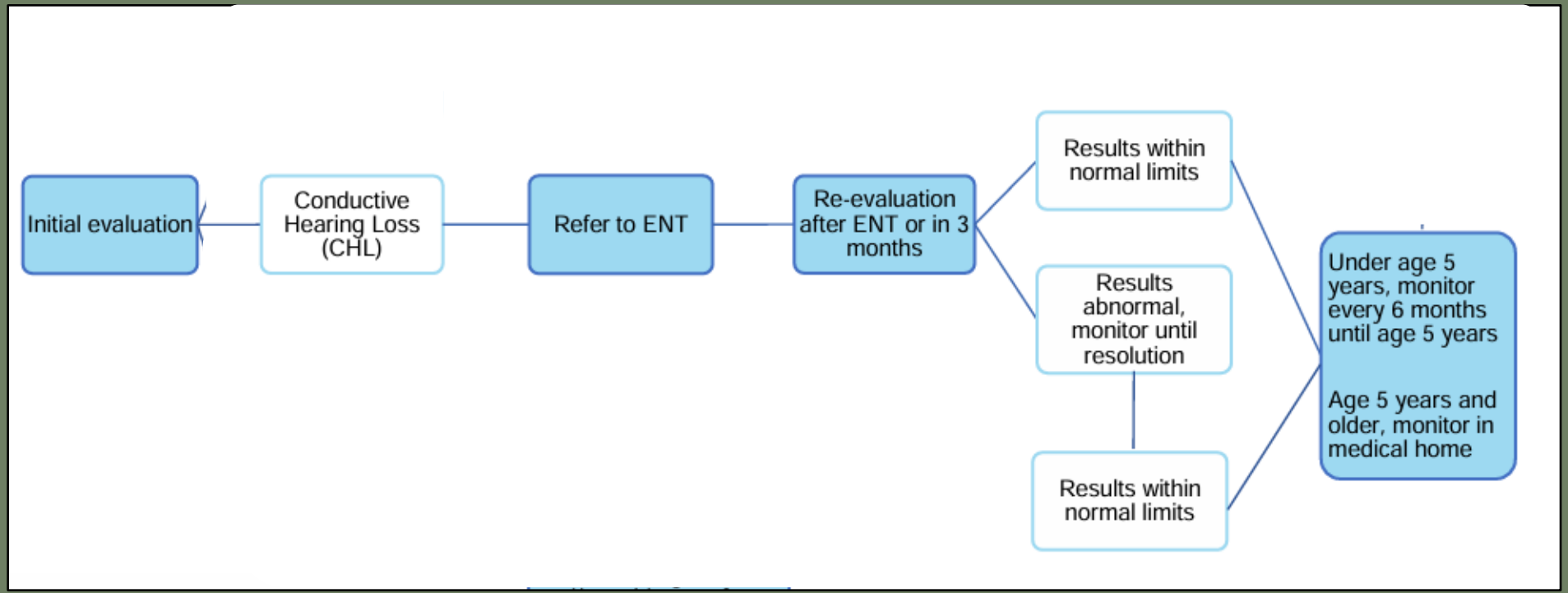
Audiologic surveillance flow chart



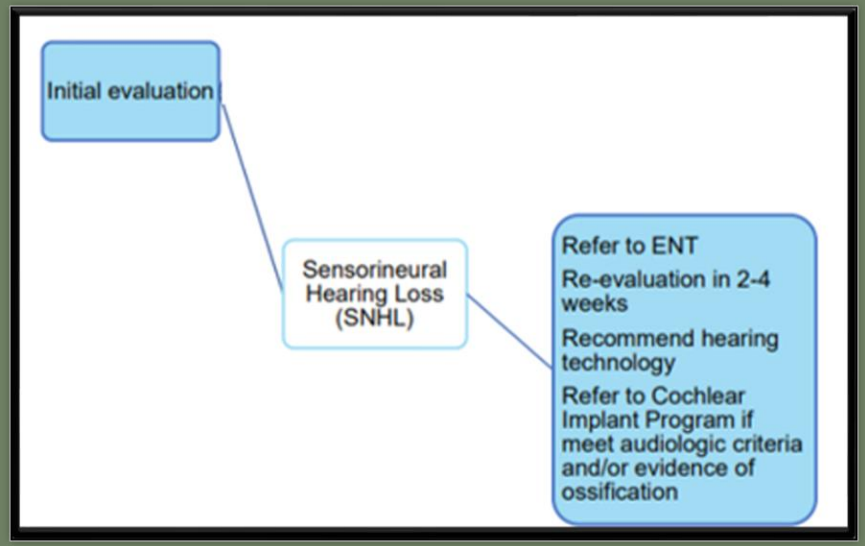
Monitoring – normal hearing sensitivity



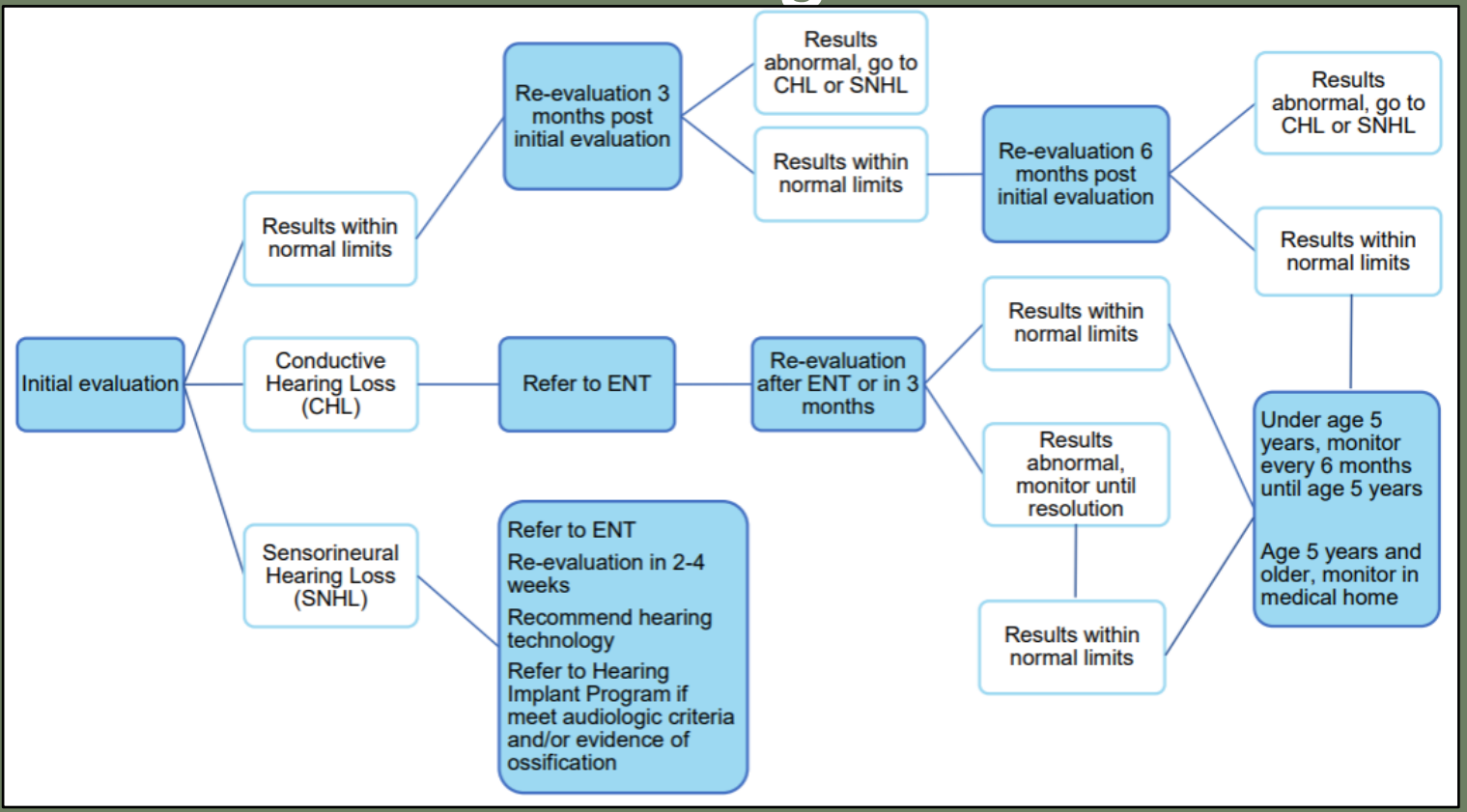
Monitoring – conductive hearing loss



Monitoring – sensorineural hearing loss

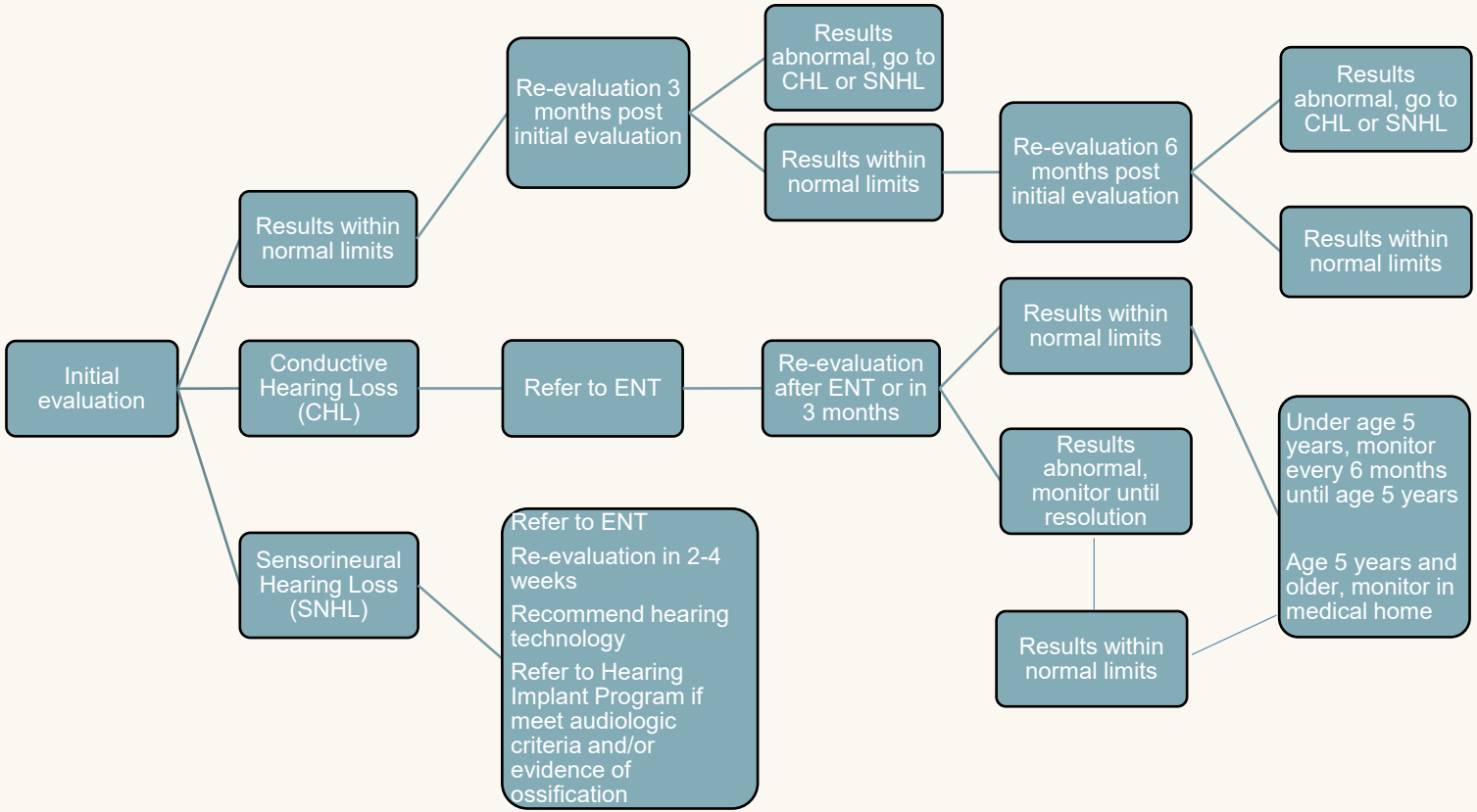


Bacterial Meningitis Audiologic Surveillance



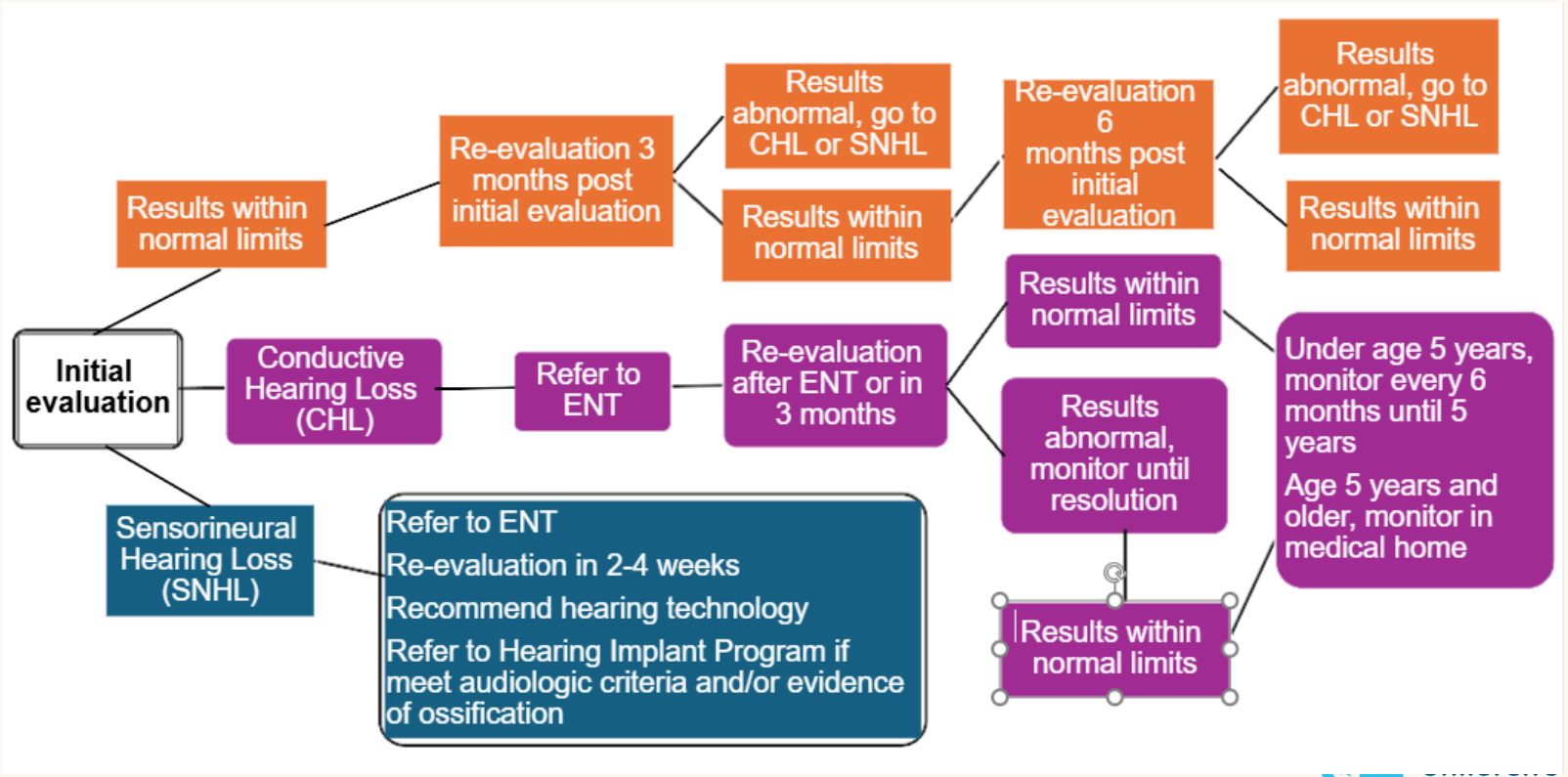
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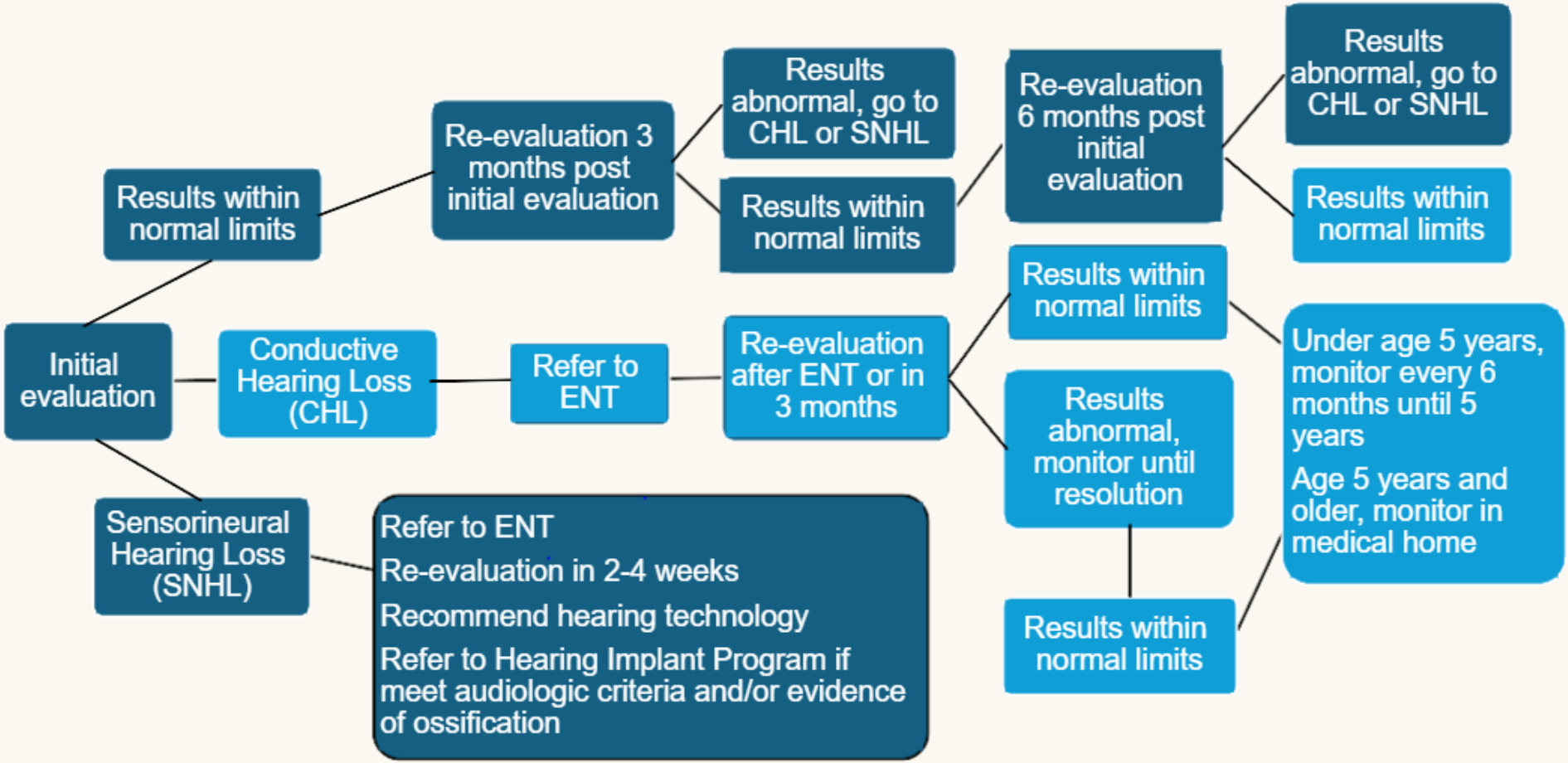
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Bacterial Meningitis Audiologic Surveillance




Initial evaluation
Results within normal limits
Re-evaluation 3 months post initial evaluation
Results abnormal, go to CHL or SNHL
Results within normal limits
Re-evaluation 6 months post initial evaluation
Results abnormal, go to CHL or SNHL
Results within normal limits
Conductive Hearing Loss (CHL)
Refer to ENT
Re-evaluation after ENT or in 3 months
Results within normal limits
Results abnormal, monitor until resolution
Results within normal limits
Under age 5 years, monitor every 6 months until 5 years
Age 5 years and older, monitor in medical home
Sensorineural Hearing Loss (SNHL)
Refer to ENT
Re-evaluation in 2-4 weeks
Recommend hearing technology
Refer to Hearing Implant Program if meet audiologic criteria and/or evidence of ossification

Outcome

4 months	**Profound bilateral SNHL confirmed**	5 months
Age at meningitis diagnosis		Bilateral cochlear implantation

- Bilateral severe to profound sensorineural hearing loss was identified via natural sleep ABR evaluation
- The patient received bilateral cochlear implants at age 5 months and continues with outpatient audiologic and medical management
- Collaboration with Audiology on the clinical care pathway was crucial to protect this patient's critical window for implantation