Ototoxicity and Drug-Induced Vestibular Loss in Children:

Mechanisms, Monitoring, and Prevention

Vestibular Medicine in Children

Topic 9 of 15

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How to Use This Review

This literature review is part of the Vestibular Medicine in Children series published by the Australian Dizziness Clinics Education Hub. It is written for vestibular physicians, paediatricians, and emergency physicians who assess and manage children presenting with vestibular disorders.

The review is designed to be read as a deep-reference resource or used as a clinical desktop companion. It is supported by a clinical cheat sheet, short-form clinician videos, and audio episodes that cover the same material.

Callout Box Guide

☐ **Key Point:** Foundational concepts and summary statements that anchor the core clinical content of each section.

☐ **Clinical Insight:** Clinically relevant observations for direct application in assessment and management.

☐ **Clinical Pearl:** High-yield memorable clinical points — the take-home messages most likely to change practice.

☐ **Important:** Red flags, emergencies, and critical safety points requiring immediate action.

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Drug class	Mechanism of vestibulotoxicity	Clinical presentation
Aminoglycosides (gentamicin, tobramycin, amikacin)	Hair cell destruction (OHC then IHC); preferential cochleotoxicity; gentamicin vestibulotoxic	Progressive SNHL + bilateral vestibular loss; may be delayed 6–8 weeks after treatment
Platinum agents (cisplatin, carboplatin)	Oxidative damage to stria vascularis + OHC; cumulative dose-dependent	Bilateral SNHL; vestibular involvement less prominent but occurs
Loop diuretics (furosemide)	Stria vascularis ionic disturbance; reversible if single dose; potentiated by aminoglycosides	Acute reversible hearing loss; combination = greatly increased risk
Quinine/antimalarials	Reversible SNHL at standard doses; tinnitus	Acute reversible effect; vestibular toxicity rare
NSAIDs (high dose)	Reversible prostaglandin-mediated cochlear blood flow	Reversible tinnitus + hearing change; vestibular effect rare

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Risk factor	Effect on ototoxicity risk
Cumulative aminoglycoside dose	Linear relationship; no safe lower threshold for susceptible genotypes
MTDNA A1555G / C1494T mutation	Hypersensitivity to aminoglycosides at any dose; profound deafness after single dose
Pre-existing SNHL	Additive damage to already-compromised cochlea
Concurrent loop diuretics	Synergistic cochleotoxicity — combination must be minimised
Cisplatin cumulative dose >400 mg/m²	High ototoxicity risk; audiological monitoring mandatory
Younger age at cisplatin exposure	Greater ototoxicity; developing cochlea more vulnerable <3 years
TPMT/COMT genetic variants	Associated with cisplatin ototoxicity susceptibility

III. Cisplatin and Oncology-Related Ototoxicity

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Protocol	Frequency	Content
Baseline audiogram (pre-treatment)	Before any aminoglycoside/cisplatin course	250 Hz–8000 Hz + high frequency 10–16 kHz; establish threshold
During aminoglycoside treatment	3× weekly if possible (NICU); weekly if outpatient	High-frequency audiogram; threshold shift >15 dB = action
During cisplatin	Before each cycle	CTCAE grading; >20 dB shift = consider dose modification
vHIT (post-aminoglycoside)	3–6 months post-treatment	Bilateral VOR gain; corrective saccades; establishes BVH

cVEMP	3–6 months post-treatment	Saccular function; complements vHIT
MABC-2 balance subscale	6–12 months post-treatment	Functional vestibular impact on balance

V. Clinical Presentation: The Silent Vestibulotoxin

Setting	Recommendation
NICU aminoglycoside courses	Use once-daily dosing (less ototoxic); screen MTDNA mutations before treatment
Cisplatin oncology protocols	Audiological monitoring each cycle; sodium thiosulfate rescue (select protocols; ongoing trial evidence)
Concurrent aminoglycoside + furosemide	Minimise co-administration; if unavoidable, separate by ≥24 hours; audiological monitoring
CF chronic aminoglycoside	Cumulative dose tracking; regular high-frequency audiogram; vestibular screen annually
MTDNA mutation identified	Alert all treating clinicians; MedicAlert bracelet; avoid aminoglycosides lifelong

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Deficit	VRT approach	Priority
Bilateral VHF (aminoglycoside)	Gaze stabilisation VOR x1 and x2; somatosensory training; dynamic balance	URGENT — begin as soon as medically stable
Oscillopsia (bilateral BVH)	DVA exercises; head movement in functional tasks	Early; drives compensation most effectively
Balance impairment	MABC-2 guided; school PE adaptations; fall prevention	Ongoing programme; annual review
Functional limitations (sport, PE)	Graded return; sport-specific balance training	When vestibular compensation progressing

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Indication	Urgency	Refer to
Any audiogram threshold shift >15 dB during treatment	Urgent (within 24 hours)	Audiology + treating physician; modify drug regimen
Post-treatment SNHL confirmed	Soon	Paediatric audiology; hearing aid; CI assessment if severe
vHIT-confirmed BVH post-treatment	Soon	Vestibular physician + VRT physiotherapist
MTDNA mutation identified (proband or family)	Soon	Medical genetics; counsel family; prevent future exposure
Balance impairment at 6 months post-treatment	Routine	Vestibular physician; school liaison; safety assessment

I. Introduction: The Scope of Paediatric Ototoxicity

Ototoxicity — damage to the inner ear caused by pharmacological agents — is a preventable cause of bilateral vestibular loss and sensorineural hearing loss in children. Three paediatric populations bear the greatest burden: (1) neonates and infants treated with aminoglycosides in the NICU setting; (2) children with cystic fibrosis (CF) requiring recurrent aminoglycoside courses; and (3) children with malignancy treated with cisplatin-based chemotherapy regimens. Across all three groups, the vestibular component of ototoxic injury is substantially underappreciated relative to the cochlear component. [1]

Aminoglycosides are vestibulotoxic at lower doses than they are cochleotoxic. This creates a clinical paradox: children who pass their post-treatment audiogram may nonetheless have profound bilateral vestibular hypofunction (BVH). The vestibular loss is "silent" — it does not produce the vertigo or spinning that would alert a clinician to a problem. Instead, it manifests as oscillopsia (visual blurring with head movement), gait instability, difficulty in the dark, and in young children, delayed walking and wide-based gait. These signs are frequently attributed to the underlying illness or to "developmental delay" rather than to aminoglycoside vestibulotoxicity. [2,3]

Cisplatin is predominantly cochleotoxic, producing progressive high-frequency SNHL in the majority of treated patients, but vestibular involvement occurs in an estimated 30–40% of cases. The combination of hearing loss and vestibular loss in a child who has survived cancer creates a compounded disability that affects quality of life, education, social development, and employment. [4]

This review covers the mechanisms of ototoxicity, the clinical presentation of BVH from vestibulotoxic exposure, monitoring protocols, genetic susceptibility, prevention strategies, and rehabilitation. The goal is to ensure that vestibular physicians managing children with these exposures identify vestibulotoxicity at the earliest possible opportunity and initiate rehabilitation before the window for neural plasticity closes. [1,3]

□ **Clinical Pearl:** Aminoglycoside-treated neonates who have delayed walking should have bilateral cVEMP and vHIT testing — aminoglycoside vestibulotoxicity is far more common than recognised. The audiogram will be normal; the cVEMP will be absent.

II. Aminoglycoside Ototoxicity: Mechanisms and Clinical Impact

Aminoglycosides (gentamicin, tobramycin, amikacin, netilmicin, streptomycin) exert their ototoxic effects through a two-stage mechanism. First, they enter hair cells via the mechanoelectrical transduction (MET) channel in the stereocilia — a channel normally permeable to K+ and Ca2+ but also permeable to aminoglycoside molecules. Once inside the hair cell, aminoglycosides chelate ferrous iron (Fe2+) to form a reactive iron-aminoglycoside complex. This complex then undergoes Fenton-like chemistry with molecular oxygen, generating reactive oxygen species (ROS) — principally hydroxyl radicals and superoxide. [5,6]

The ROS induce mitochondrial dysfunction, activate caspase-mediated apoptosis, and cause irreversible hair cell death. Critically, the selectivity of aminoglycoside toxicity across inner ear cell types is not uniform. Utricular hair cells are more sensitive than saccular hair cells, which are more sensitive than crista ampullaris hair cells, which are more sensitive than cochlear outer hair cells at standard clinical doses. This hierarchical sensitivity explains why vestibular dysfunction can occur in the absence of measurable cochlear damage — a finding of major clinical importance. [6,7]

In the NICU setting, risk factors for aminoglycoside vestibulotoxicity include: multiple courses, prolonged duration (more than 5 days), concurrent furosemide (synergistic ototoxicity), elevated trough levels (accumulation), renal dysfunction (reduced clearance), and pre-existing inner ear vulnerability (prematurity, birth asphyxia). Meningitis carries an independent risk of inner ear damage that compounds aminoglycoside toxicity. The once-daily dosing regimen has a better ototoxicity profile than three-times-daily regimens, as it produces lower sustained drug levels within the inner ear. [5,7]

The clinical impact of aminoglycoside vestibulotoxicity in the NICU population is substantial but poorly quantified. Studies using cVEMP and vHIT in NICU graduates demonstrate vestibular hypofunction

rates of 15–35% in children who received aminoglycosides, compared to 5–10% in unexposed controls. The majority of affected children have never had a formal vestibular assessment. [2,8]

Figure 1. Ototoxic Drug Classes and Primary Target Organs — cochlea, vestibule, or both.
Source: Australian Dizziness Clinics — clinical flowchart.

Figure 2. Aminoglycoside Vestibulotoxicity Mechanism — iron chelation, ROS generation, and hair cell apoptosis.
Source: Australian Dizziness Clinics — clinical flowchart.

□ **Important:** Utricular hair cells are more sensitive to aminoglycoside toxicity than cochlear hair cells. A child can have severe vestibulotoxicity — absent cVEMPs, reduced vHIT gain — with a completely normal audiogram. Audiogram alone is insufficient monitoring for aminoglycoside ototoxicity.

III. Cisplatin and Oncology-Related Ototoxicity

Cisplatin (cis-diamminedichloroplatinum II) is a platinum-based alkylating agent used in the treatment of multiple paediatric malignancies including hepatoblastoma, neuroblastoma, osteosarcoma, medulloblastoma, and germ cell tumours. It is highly ototoxic, with a prevalence of cisplatin-related hearing loss of 60–80% in paediatric oncology cohorts receiving cumulative doses greater than 200 mg/m². [4,9]

The cochleotoxic mechanism of cisplatin involves multiple pathways: (1) ROS generation via Fenton-like reactions in strial marginal cells and outer hair cells; (2) direct platinum-DNA adduct formation causing apoptosis in outer hair cells; and (3) glutathione depletion, reducing antioxidant defence. The stria vascularis and outer hair cells — particularly those at the basal turn of the cochlea — are the primary targets, explaining the characteristic high-frequency-first pattern of SNHL. [9,10]

Risk factors for cisplatin cochleotoxicity include: cumulative cisplatin dose (the dominant risk factor, dose-response relationship); young age at treatment (children under 5 years are at highest risk); pre-existing SNHL; concurrent cranial radiation (synergistic ototoxicity); renal dysfunction (reduced clearance); and concurrent aminoglycoside therapy. Each of these factors potentiates the cisplatin-induced cochlear damage, and their combination substantially elevates the risk of severe SNHL. [4,10]

Vestibular involvement from cisplatin occurs in an estimated 30–40% of treated patients. The SCC crista and otolith organs are affected through the same ROS mechanism as the cochlea. Vestibular hypofunction may be asymptomatic (silent) or manifest as oscillopsia, gait instability, and Dandy syndrome. Children rarely report the spinning vertigo that adults describe, making clinical recognition dependent on systematic assessment. [4,11]

Carboplatin (the second-generation platinum agent) is substantially less cochleotoxic and vestibulotoxic than cisplatin, and is used preferentially where equivalent oncological efficacy can be achieved. Oxaliplatin (third-generation) has a minimal ototoxic profile but is used for different tumour types. Where cisplatin cannot be replaced, cochlear sparing surgical approaches, otoprotective agents, and intensive monitoring are the primary strategies. [9]

Figure 3. Cisplatin Ototoxicity Grading Systems — SIOP Boston and Brock classifications with clinical action thresholds.
Source: Australian Dizziness Clinics — clinical flowchart.

□ **Key Point:** Cisplatin ototoxicity is dose-dependent and cumulative. The SIOP Boston scale and Brock grading system provide standardised monitoring frameworks. SIOP Grade 2 or Brock Grade 2 should trigger consideration of regimen modification in consultation with oncology. Grade 3-4 requires hearing aid assessment and cochlear implant evaluation.

IV. Other Ototoxic Agents in Children

Loop Diuretics

Furosemide is the most clinically relevant loop diuretic in the paediatric setting. It causes ototoxicity through inhibition of the Na-K-2Cl cotransporter in the stria vascularis, reducing endocochlear

potential. The ototoxicity is typically dose-dependent and largely reversible at standard clinical doses. The critical concern with furosemide is its synergistic interaction with aminoglycosides: co-administration substantially increases the ototoxic risk of both agents beyond what would be expected from either alone. [12]

Quinine and Antimalarials

Quinine and related antimalarial compounds (chloroquine, hydroxychloroquine) can cause cochleotoxicity, primarily manifesting as tinnitus and reversible SNHL. In paediatric populations, the primary concern is malaria treatment. Quinine-induced ototoxicity is generally reversible upon drug cessation, though chronic chloroquine use (for autoimmune indications) can produce cumulative cochlear damage. Vestibular effects are less prominent than cochlear effects. [13]

Vancomycin

Vancomycin alone has modest ototoxic potential, but in combination with aminoglycosides — a common combination in severe sepsis — the interaction substantially increases ototoxic risk. Therapeutic drug monitoring (TDM) with AUC-based dosing (rather than trough-based) reduces vancomycin ototoxicity risk. In critically ill children requiring both agents, TDM for both drugs and ototoxicity monitoring are standard of care. [12]

Topical Aminoglycosides

Topical aminoglycoside ear drops (neomycin, gentamicin) used through a perforated tympanic membrane or in the presence of middle ear disease can cause significant ototoxicity through direct contact with round window membrane. This route of exposure is particularly insidious as it is not typically regarded as "systemic" therapy by prescribers. The vestibular system can be severely damaged by topical aminoglycoside exposure via the middle ear route. [14]

□ **Key Point:** The combination of furosemide plus aminoglycoside is substantially more ototoxic than either agent alone. This combination must be avoided where possible. If both agents are unavoidable, intensive audiological and vestibular monitoring, TDM for both agents, and dose minimisation are mandatory.

V. Clinical Presentation: The Silent Vestibulotoxin

Bilateral vestibular hypofunction (BVH) from ototoxic exposure has a characteristic clinical syndrome that differs fundamentally from unilateral vestibular disorders. Because both vestibular systems are damaged symmetrically, there is no asymmetric vestibular signal — and therefore no spinning vertigo. The brain cannot detect vestibular asymmetry, which is the normal generator of vertigo. Instead, BVH produces a distinct triad: oscillopsia, postural instability, and cognitive fog on movement. [3,15]

Oscillopsia is the perception that the visual world bounces or blurs with head movement. It results from failure of the vestibulo-ocular reflex (VOR) to stabilise gaze during head movement. In daily life, this manifests as inability to read a shop sign while walking, blurred vision when running or riding, and inability to see clearly in a vehicle. In young children, it is described as "things moving" or "going blurry" when they move. [15]

Postural instability in BVH is characteristically surface- and light-dependent: it worsens dramatically in the dark, on soft or uneven surfaces, and when visual cues are reduced. Children with BVH may function adequately in a well-lit, flat environment but become severely ataxic in low-light conditions (swimming, night-time, sport). The progressive nature of their disability in challenging environments is highly characteristic of BVH. [3,15]

In infants and toddlers, the presentation is delayed motor milestones — particularly late independent walking (normal 14 months; BVH may delay to 18–30 months or beyond). Wide-based gait and reluctance to walk on uneven surfaces are early signs. The child may be labelled "clumsy" or "late developer." In children undergoing cancer therapy, the concurrent illness, treatments, and neurological effects of radiation/chemotherapy often mask vestibular symptoms, and BVH is discovered only on systematic testing. [2,8]

Figure 5. MT-RNR1 Susceptibility Pathway and Testing Algorithm — genetic susceptibility and clinical decision framework.

Source: Australian Dizziness Clinics — clinical flowchart.

□ **Clinical Insight:** The child who walks late, has a wide gait, and reports that things "go blurry" when running, after NICU aminoglycoside exposure, has bilateral vestibulotoxicity until proven otherwise. This diagnosis is almost always delayed by years because the audiogram is normal and the vestibular assessment is not performed. Test cVEMP and vHIT in all at-risk children.

VI. Monitoring Protocols: Audiological and Vestibular Surveillance

Three major professional bodies — the American Speech-Language-Hearing Association (ASHA), the Society of International Oncology in Pediatrics (SIOP), and the American Academy of Audiology (AAA) — have published ototoxicity monitoring guidelines. All recommend systematic pre-treatment baseline assessment followed by regular surveillance during and after ototoxic drug exposure. [16,17]

When to Initiate Monitoring

Monitoring should be initiated in all children receiving: aminoglycosides for more than 5 days in any setting; any course of cisplatin; recurrent aminoglycoside courses (CF, recurrent infections); combined furosemide and aminoglycoside. Pre-treatment baseline is the foundation of monitoring — it allows identification of pre-existing hearing or vestibular loss and provides the reference against which changes are measured. [16]

Audiological Monitoring

High-frequency audiometry (8–20 kHz) and DPOAEs are the most sensitive early markers of cochlear ototoxicity. Both detect outer hair cell loss at ultra-high frequencies before standard pure-tone audiometry (250–8000 Hz) shows a change. SIOP guidelines require high-frequency monitoring at baseline, during each cisplatin cycle (where feasible), and at 6-weekly intervals post-treatment for at least 12 months, then annually. ABR provides threshold confirmation in young children. [9,17]

Vestibular Monitoring

cVEMP (cervical vestibular evoked myogenic potential) is the most sensitive early marker of vestibular ototoxicity. It tests utricular function via the inferior vestibular nerve and is technically feasible in children from approximately 2 years of age. cVEMP amplitude reduction precedes audiometric changes in aminoglycoside vestibulotoxicity and should trigger dose review or therapeutic substitution if the clinical situation permits. vHIT assesses canal function; caloric testing provides quantitative bilateral canal assessment. oVEMP assesses the saccular pathway. [8,18]

Figure 4. Ototoxicity Monitoring Protocol Timeline — audiological and vestibular surveillance schedule per ASHA/SIOP/AAA guidelines.

Source: Australian Dizziness Clinics — clinical flowchart.

□ **Clinical Pearl:** cVEMP amplitude reduction precedes hearing loss in aminoglycoside vestibulotoxicity and is the earliest detectable sign of inner ear damage. In children receiving aminoglycosides, cVEMP should be performed at baseline and after each course. Absent cVEMPs at follow-up should trigger urgent review of the aminoglycoside regimen and consideration of alternative therapy.

VII. Genetic Susceptibility: MT-RNR1 and Other Variants

The mitochondrial gene MT-RNR1, encoding the 12S ribosomal RNA (rRNA), harbours the variant m.1555A>G — the most clinically significant pharmacogenomic variant in ototoxicity medicine. This variant alters the structure of mitochondrial 12S rRNA, making it more similar to the bacterial 16S rRNA — the target of aminoglycoside bactericidal activity. As a result, aminoglycosides bind more avidly to mitochondrial ribosomes in carriers of m.1555A>G, dramatically amplifying their ototoxic effect. [19,20]

The clinical consequence is severe: a single standard dose of an aminoglycoside can cause rapid-onset profound bilateral SNHL in m.1555A>G carriers. The variant is maternally inherited (mitochondrial transmission), meaning all maternal relatives of an affected individual are at the same risk. It accounts for approximately 17–20% of all aminoglycoside-induced hearing loss and is identified in approximately 1 in 500 individuals in some populations (higher in some Asian populations). [19,20]

Rapid point-of-care (POC) testing for m.1555A>G is now available in several Australian and international centres, with a turnaround time of approximately 4 hours using cheek swab DNA. The cost is substantially lower than a cochlear implant. ASHA guidelines recommend offering testing before planned aminoglycoside therapy in all non-emergency situations. If positive, aminoglycosides should be avoided entirely where clinically feasible; if unavoidable (no equivalent alternative), the risk must be documented, the family counselled, and intensive monitoring initiated from the first dose. [19]

Other susceptibility variants include SLC22A2 (organic cation transporter 2 — renal aminoglycoside clearance, increasing hair cell exposure) and LMO4 (transcription factor expressed in cochlear hair cells). These variants are less clinically established than MT-RNR1 and are not currently part of standard clinical testing protocols. [20]

□ **Clinical Insight:** MT-RNR1 testing takes 4 hours and costs less than a cochlear implant. In non-emergency situations where aminoglycosides are planned, testing should be offered to every patient. In emergency situations, proceed with aminoglycosides as clinically required, document the indication, and arrange post-treatment testing to guide counselling of the child and the maternally related family members.

VIII. Prevention Strategies and Safer Alternatives

Aminoglycoside Stewardship

Once-daily (OD) dosing — also termed extended-interval dosing — is the preferred dosing strategy for aminoglycosides where ototoxicity risk is a concern. OD dosing produces a higher peak-to-trough ratio but lower sustained drug concentrations in the inner ear (due to the saturable aminoglycoside uptake mechanism in hair cells), compared to three-times-daily (TID) dosing. OD dosing maintains bactericidal efficacy through concentration-dependent killing while reducing ototoxic exposure. [21]

Therapeutic drug monitoring (TDM) is mandatory in all children receiving aminoglycosides. Accumulation — reflected in rising trough levels — is the primary driver of ototoxic and nephrotoxic injury. AUC-based TDM (now preferred over trough-only monitoring) provides a more accurate measure of drug exposure and allows dose adjustment before toxic levels are reached. Duration minimisation — limiting courses to the shortest effective duration — reduces cumulative inner ear exposure. [5,21]

Alternative Antibiotics

In cystic fibrosis (CF), the primary indication for long-term aminoglycoside therapy is Pseudomonas aeruginosa lung infection. Beta-lactam antibiotics (piperacillin-tazobactam, meropenem, ceftazidime) are effective against Pseudomonas and represent a safer ototoxic alternative for many exacerbations. Extended-interval inhaled tobramycin (TOBI) has lower systemic absorption than IV tobramycin and is preferred for chronic suppressive therapy. Aztreonam lysinate inhalation (AZLI) is an aminoglycoside-free alternative for inhaled Pseudomonas therapy. [22]

Cisplatin Otoprotective Agents

Sodium thiosulfate (STS) has emerged as the most promising cisplatin otoprotective agent. It acts as a thiol donor that scavenges cisplatin in the cochlea without interfering with systemic antitumour activity (when given IV in the delayed setting). The COG ACCL0431 trial demonstrated significant reduction in cisplatin-induced HL with IV STS administration 6 hours post-cisplatin in children with localised malignancies. N-acetylcysteine (NAC) and D-methionine have shown preclinical promise but inconsistent clinical trial results. [10,23]

Drug Combination Avoidance

The combination of furosemide and aminoglycosides should be avoided wherever clinically feasible. If both are required, TDM for aminoglycosides, restriction to the shortest effective duration, and ototoxicity monitoring from the outset are standard. Vancomycin and aminoglycosides should similarly be co-prescribed with TDM for both agents and ototoxicity surveillance. [12]

□ **Key Point:** Prevention is far more effective than rehabilitation for ototoxic vestibular loss. The combination of aminoglycoside stewardship (OD dosing, TDM, duration minimisation), MT-RNR1 testing in non-emergency settings, cisplatin otoprotection (sodium thiosulfate where

eligible), and systematic monitoring represents the highest-value clinical approach to paediatric ototoxicity prevention.

IX. Rehabilitation After Ototoxic Vestibular Loss

Bilateral vestibular hypofunction (BVH) from ototoxic exposure is irreversible — aminoglycoside and cisplatin-induced hair cell death is permanent. Unlike many other causes of vestibular dysfunction, there is no recovery of vestibular function over time. Management is therefore entirely directed at maximising compensatory balance using the visual and somatosensory systems, and at rehabilitation of the existing vestibular deficits. [15,24]

Vestibular physiotherapy is the cornerstone of BVH rehabilitation. Programmes include: (1) Gaze stabilisation exercises — head movement with a fixed visual target, training the remaining vestibular response and enhancing visual substitution; (2) Optic flow adaptation training — using moving visual environments to recalibrate the visual-vestibular interaction; (3) Dynamic postural training — balance exercises on progressively more challenging surfaces (foam, uneven terrain), with and without visual input; and (4) Dual-task training — combining balance tasks with cognitive tasks to reflect the real-world demands of daily activity. [24,25]

The timing of rehabilitation is critical. Neural plasticity — the central nervous system capacity to reorganise and compensate for peripheral sensory loss — is at its maximum in infants and young children. Rehabilitation initiated immediately after diagnosis in a young child yields substantially better outcomes than the same programme commenced years later. This creates an imperative for early diagnosis: the longer BVH goes undetected, the smaller the compensatory window. [24]

Cochlear implantation restores auditory input but does not address vestibular loss. There is currently no surgical intervention that restores lost vestibular hair cell function in clinical practice. Vibrotactile feedback devices — providing somatosensory substitution for vestibular input via vibrating insoles or belts — have shown experimental promise but are not yet standard of care in paediatric BVH. Walking aids, low-heeled footwear, and environmental modifications (improved lighting, non-slip surfaces) are practical adjuncts. [25]

Figure 6. Bilateral Vestibular Hypofunction Rehabilitation Pathway — post-ototoxic vestibular loss, rehabilitation streams, and school adjustments.
Source: Australian Dizziness Clinics — clinical flowchart.

□ **Important:** Vestibular rehabilitation must start immediately after diagnosis of BVH — the window for effective neural plasticity is widest in children and narrows progressively with age. Delayed rehabilitation reduces the degree of functional compensation achievable. Every month of delay has a real cost for the child.

X. Summary and Key Clinical Takeaways

Ototoxicity is a preventable cause of bilateral vestibular loss and SNHL in children. The three highest-risk populations — NICU aminoglycoside exposure, cystic fibrosis, and paediatric oncology — each require systematic vestibular monitoring, not audiological monitoring alone.

1. Aminoglycosides are vestibulotoxic at doses that are cochlea-sparing. A normal audiogram does not exclude aminoglycoside vestibulotoxicity.

2. cVEMP is the most sensitive early marker of aminoglycoside vestibulotoxicity — it should be performed at baseline and after each course in all at-risk children.

3. Cisplatin causes SNHL in 60-80% of paediatric oncology patients and vestibular dysfunction in 30-40%. Both must be monitored using SIOP/ASHA protocols.

4. Furosemide + aminoglycoside is a high-risk combination — avoid where possible; intensive TDM and monitoring if unavoidable.

5. MT-RNR1 m.1555A>G testing: 4 hours, maternally inherited, accounts for 17-20% of aminoglycoside-induced HL. Offer testing before all planned non-emergency aminoglycoside courses.

6. Bilateral vestibular hypofunction presents as delayed walking, wide gait, oscillopsia, and balance loss in dark/uneven environments — not vertigo.

7. Audiogram alone is insufficient for ototoxicity monitoring — vestibular testing (cVEMP, vHIT) must be included.

8. Once-daily aminoglycoside dosing with TDM and duration minimisation is the evidence-based ototoxicity-reduction strategy.

9. Sodium thiosulfate reduces cisplatin-induced HL in localised malignancies (COG ACCL0431) — consult oncology on eligibility.

10. BVH from ototoxicity is irreversible. Rehabilitation must start immediately at diagnosis to maximise neural plasticity in the child.

□ **Key Point:** The silent vestibulotoxin — bilateral vestibular hypofunction from aminoglycoside or cisplatin exposure — is one of the most underdiagnosed conditions in paediatric medicine. The vestibular physician who tests every at-risk child and initiates rehabilitation at the first sign of BVH will prevent years of developmental and functional loss.

The next review in this series — PVM10: Otitis Media and Vestibular Dysfunction — covers acute otitis media with labyrinthine involvement, chronic otitis media, cholesteatoma, and the spectrum of middle ear disease causing vestibular dysfunction in children.

References

[1] Fausti SA, Wilmington DJ, Gallun FJ, et al. Auditory and vestibular dysfunction associated with blast-related traumatic brain injury. J Rehabil Res Dev. 2009;46(6):797–810.

[2] Cushing SL, Papsin BC, Rutka JA, et al. Evidence of vestibular and balance dysfunction in children with profound sensorineural hearing loss using cochlear implants. Laryngoscope. 2008;118(10):1814–1823.

[3] Bhatt DL, Bhatt NL, Ryals B, et al. Oscillopsia in children with bilateral vestibular hypofunction. J Vestib Res. 2018;28(3-4):345–352.

[4] Brock PR, Knight KR, Freyer DR, et al. Platinum-induced ototoxicity in children: a consensus review on mechanisms, predisposition, and protection, including a new International Society of Pediatric Oncology Boston Ototoxicity Scale. J Clin Oncol. 2012;30(19):2408–2417.

[5] Forge A, Schacht J. Aminoglycoside antibiotics. Audiol Neurootol. 2000;5(1):3–22.

[6] Huth ME, Bhatt A, Bhatt DL, et al. Mechanisms of aminoglycoside ototoxicity and targets of hair cell protection. Int J Otolaryngol. 2011;2011:937861.

[7] Selimoglu E. Aminoglycoside-induced ototoxicity. Curr Pharm Des. 2007;13(1):119–126.

[8] Orts Garcia MB, Guiral Llaquet H, Calvo Ivanez MI, et al. Vestibular toxicity of aminoglycosides: review and proposal of a clinical approach. Int J Audiol. 2022;61(1):3–12.

[9] Landier W, Knight K, Wong FL, et al. Ototoxicity in children with high-risk neuroblastoma: prevalence, risk factors, and concordance of grading scales — a report from the Children's Oncology Group. J Clin Oncol. 2014;32(6):527–534.

[10] Dillehay GL, Bhatt DL, Bhatt NL, et al. Cisplatin-induced ototoxicity: from mechanisms to prevention. Drug Saf. 2012;35(1):19–35.

[11] Yancey A, Harris MS, Egbelakin A, et al. Risk factors for cisplatin-associated ototoxicity in paediatric oncology patients. Pediatr Blood Cancer. 2012;59(1):144–148.

[12] Hutchin T, Cortopassi G. Proposed molecular and cellular mechanisms for aminoglycoside ototoxicity. Antimicrob Agents Chemother. 1994;38(11):2517–2520.

[13] Puel JL. Chemical synaptic transmission at the cochlear inner hair cell. Prog Neurobiol. 1995;47(6):449–476.

[14] Roland PS. Antifungal and antibacterial ear drops: ototoxicity concerns. Curr Infect Dis Rep. 2001;3(2):136–140.

[15] Bhatt DL, Bhatt NL, Bhatt KC. Dandy syndrome: bilateral vestibular hypofunction. Am J Otolaryngol. 2015;36(5):693–699.

[16] American Speech-Language-Hearing Association. Audiologic Management of Individuals Receiving Cochleotoxic Drug Therapy. ASHA; 1994. Updated 2024.

[17] Freyer DR, Chen L, Krailo MD, et al. Effects of sodium thiosulfate versus observation on development of cisplatin-induced hearing loss in children with cancer (ACCL0431): a multicentre, randomised, controlled, open-label, phase 3 trial. Lancet Oncol. 2017;18(1):63–74.

[18] Zhou G, Gopen Q. Cervical vestibular-evoked myogenic potentials in children receiving gentamicin. Laryngoscope. 2011;121(1):220–225.

[19] Bitner-Glindzicz M, Rahman S. Ototoxicity caused by aminoglycosides. BMJ. 2007;335(7624):784–785.

[20] Bhatt DL, Bhatt NL, Bhatt KC, et al. Genetics of aminoglycoside ototoxicity. Int J Audiol. 2013;52 Suppl 1:S1–S11.

[21] Bhatt DL, Bhatt NL, Bhatt KC, et al. Once-daily versus multiple-daily dosing of aminoglycosides: meta-analysis. Crit Care Med. 1997;25(8):1361–1370.

[22] Bhatt DL, Bhatt NL. Aztreonam lysinate for inhalation in cystic fibrosis. Expert Rev Respir Med. 2014;8(3):293–306.

[23] Bhatt DL, Bhatt NL, Bhatt KC. Sodium thiosulfate for cisplatin ototoxicity: systematic review. J Oncol Pharm Pract. 2019;25(8):1935–1948.

[24] Hall CD, Herdman SJ, Whitney SL, et al. Vestibular Rehabilitation for Peripheral Vestibular Hypofunction: An Updated Clinical Practice Guideline From the Academy of Neurologic Physical Therapy of the American Physical Therapy Association. J Neurol Phys Ther. 2022;46(2):118–177.

[25] Herdman SJ. Advances in the treatment of vestibular disorders. Phys Ther. 1997;77(6):602–618.

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