



Pendred Syndrome: Clinical Manifestations, Diagnostic Strategies, and Nursing Management

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Abstract

Background: Pendred syndrome is a rare autosomal recessive disorder characterized by sensorineural hearing loss, thyroid abnormalities such as goiter, and inner ear malformations including an enlarged vestibular aqueduct and Mondini dysplasia. Its underlying cause is primarily pathogenic variants in the *SLC26A4* gene, which impair pendrin function in the inner ear, thyroid, and renal epithelium.

Aim: This study aims to summarize the clinical manifestations, diagnostic strategies, and comprehensive nursing management essential for optimizing outcomes in patients with Pendred syndrome.

Methods: A detailed review of current clinical knowledge was conducted focusing on epidemiology, pathophysiology, diagnostic evaluation—including audiologic testing, thyroid assessment, imaging, and genetic analysis—and multidisciplinary management approaches.

Results: Findings highlight that Pendred syndrome commonly presents during early childhood with bilateral, often progressive sensorineural hearing loss, exacerbated by minor trauma. Thyroid involvement typically manifests as euthyroid goiter during late childhood or adolescence, with some patients developing hypothyroidism. Inner ear anomalies such as enlarged vestibular aqueducts are characteristic and correlate with disease severity. Management is supportive, incorporating hearing aids or cochlear implantation, thyroid hormone replacement when needed, vestibular rehabilitation, and genetic counseling. Nursing plays a key role in education, monitoring, perioperative care, and long-term patient support.

Conclusion: Early diagnosis, routine monitoring, and coordinated multidisciplinary care significantly improve communication, metabolic stability, and quality of life for affected individuals.

Keywords: Pendred syndrome; *SLC26A4*; sensorineural hearing loss; enlarged vestibular aqueduct; goiter; thyroid dysfunction; cochlear implant; nursing management; genetic counseling.

Introduction

Pendred syndrome is a rare hereditary disorder first identified in 1896, characterized by the coexistence of sensorineural hearing loss and thyroid abnormalities, particularly goiter, with or without hypothyroidism. The syndrome arises primarily from autosomal recessive mutations in the *SLC26A4* gene, which impair the function of the pendrin protein responsible for ion transport in the inner ear and thyroid gland [1][2]. This genetic defect disrupts the development of the cochlea and vestibular structures, resulting in progressive auditory and balance impairments. Pendred syndrome accounts for 7% to

15% of congenital hearing loss cases, typically manifesting as bilateral hearing deficits that may evolve gradually rather than presenting fully at birth [3]. Balance dysfunction is common, occurring in approximately two-thirds of affected individuals due to enlargement of the vestibular aqueduct. Auditory decline can be exacerbated by minor head trauma, necessitating early recognition and preventive strategies. Thyroid involvement may remain latent during early childhood, with goiter generally emerging in late childhood or early adulthood. Some patients remain euthyroid despite the presence of thyroid enlargement, emphasizing the importance of routine

thyroid function monitoring even in asymptomatic cases [4]. Management of Pendred syndrome is supportive and tailored to individual patient needs. Interventions include hearing amplification devices, vestibular rehabilitation to address balance deficits, and thyroid hormone supplementation when hypothyroidism develops. Multidisciplinary care is essential to optimize outcomes, involving audiologists, endocrinologists, and physical therapists. Genetic counseling is a critical component, providing families with information on inheritance patterns, carrier status, and the likelihood of recurrence in future offspring [5]. Early diagnosis, ongoing monitoring, and coordinated care are vital to improving quality of life for patients with Pendred syndrome and mitigating the long-term impact of sensory and endocrine complications.

Etiology

Pendred syndrome primarily results from mutations in the SLC26A4 gene, which encodes the pendrin protein, a critical anion transporter involved in the regulation of chloride, iodide, bicarbonate, and other ions [6]. The SLC26A4 gene is located on chromosome 7q22.3 and is expressed in multiple organ systems, including the inner ear, thyroid gland, kidneys, and bronchial epithelium [1][6]. Dysfunction of pendrin disrupts normal ion transport, leading to impaired endolymphatic fluid homeostasis in the inner ear and abnormal thyroid hormone synthesis, contributing to the characteristic features of sensorineural hearing loss and goiter. The severity and progression of hearing impairment are closely related to the extent of pendrin dysfunction and structural abnormalities, such as enlargement of the vestibular aqueduct. In addition to SLC26A4 mutations, less common genetic contributors have been identified. Mutations in the FOXI1 gene, which encodes a transcription factor involved in pendrin expression, and in the KCNJ10 gene, which encodes an inward-rectifying potassium channel, have been associated with Pendred syndrome [7]. Combined, mutations in SLC26A4, FOXI1, and KCNJ10 explain approximately 50% of clinically diagnosed cases. The remaining half of cases currently lack a clearly identified genetic origin, suggesting the involvement of additional, as yet unidentified genes or complex interactions between multiple genetic and environmental factors. Understanding the etiology of Pendred syndrome is crucial for early diagnosis, genetic counseling, and targeted management strategies. Identification of pathogenic mutations allows for precise risk assessment in families, guides monitoring of hearing and thyroid function, and informs decisions regarding interventions such as hearing rehabilitation and thyroid hormone therapy. Ongoing research into the molecular mechanisms underlying Pendred syndrome may expand knowledge of its genetic basis and improve approaches for prevention and personalized care [6].

Epidemiology

Pendred syndrome is a rare genetic disorder, with an estimated prevalence ranging from 7.5 to 10 cases per 100,000 live births [1][7]. Despite its rarity, it represents a significant contributor to congenital hearing loss, accounting for approximately 7.5% to 15% of all cases of congenital deafness [6][3]. This makes Pendred syndrome one of the most common causes of syndromic hearing impairment, highlighting its clinical relevance in pediatric and audiological practice [1][8]. The condition affects males and females equally, reflecting its autosomal recessive inheritance pattern. Children born to two heterozygous carrier parents have a 25% probability of inheriting the syndrome, a 50% chance of being carriers themselves, and a 25% likelihood of remaining unaffected [1]. This predictable inheritance pattern underscores the critical role of genetic counseling, particularly for families with a documented history of hearing deficits or thyroid disorders. Early identification of at-risk individuals allows for timely audiological assessment, monitoring for thyroid dysfunction, and proactive interventions to support speech, language, and cognitive development. Epidemiological data also indicate geographic and ethnic variations in prevalence, influenced by population genetics and rates of consanguinity. Certain regions with higher rates of consanguineous marriage report increased incidence of Pendred syndrome, emphasizing the need for targeted screening and public health awareness in these communities. Additionally, understanding the epidemiology of Pendred syndrome guides resource allocation for early intervention programs, hearing rehabilitation services, and specialized care for thyroid management. Accurate population-level data support planning for multidisciplinary care, genetic counseling, and research initiatives aimed at improving long-term outcomes for affected individuals [6][7][8].

Pathophysiology

Pendred syndrome is an autosomal recessive disorder resulting from biallelic mutations in the SLC26A4 gene, which encodes the multifunctional anion exchanger protein pendrin. Pendrin is expressed in several organs, including the thyroid gland, inner ear, kidneys, and bronchial epithelium, where it regulates ion transport critical for normal physiological function. Dysfunction of pendrin due to SLC26A4 mutations disrupts ion homeostasis, leading to the characteristic clinical manifestations of Pendred syndrome, including sensorineural hearing loss, vestibular dysfunction, and thyroid abnormalities [1][6]. In the inner ear, pendrin is localized within the cochlea and vestibular structures, acting as a chloride/bicarbonate exchanger. It plays a central role in the regulation of endolymphatic fluid volume, pH, and ion composition, which are essential for normal auditory and vestibular function [6]. Disruption of pendrin activity results in abnormal fluid homeostasis, enlargement of the vestibular aqueduct, and impaired mechanotransduction in cochlear hair cells. These

changes manifest clinically as progressive sensorineural hearing loss, often bilateral, and balance dysfunction in approximately 66% of affected individuals. Hearing deterioration may be gradual during early childhood but can be accelerated by minor head trauma [3]. In the thyroid gland, pendrin is expressed on the apical membrane of thyrocytes, facilitating chloride/iodide exchange that is critical for iodide efflux into the follicular lumen and subsequent hormone synthesis. Mutations in SLC26A4 partially impair organification of iodide, which may lead to goiter development. Despite structural thyroid changes, most patients remain euthyroid, highlighting a discrepancy between anatomical and functional manifestations [1][6]. Routine thyroid monitoring is therefore necessary to detect evolving dysfunction.

Pendrin is also expressed in the kidneys, particularly in type B and non-A non-B intercalated cells of the cortical collecting duct. Here, it mediates chloride reabsorption and bicarbonate secretion, contributing to acid-base homeostasis, fluid balance, and blood pressure regulation [6][9]. Pendrin deficiency can disrupt these processes, resulting in metabolic alkalosis in some cases [10]. In the respiratory system, pendrin is located on the apical surface of bronchial epithelial cells. Its chloride/bicarbonate exchange maintains airway surface liquid thickness and mucus hydration, while its thiocyanate/chloride exchange supports mucosal defense through secretion of the antioxidant SCN⁻. Dysfunctional pendrin in the airway can contribute to altered mucus production and airway inflammation, potentially exacerbating conditions such as asthma and chronic obstructive pulmonary disease [6]. The multisystem involvement of pendrin underlines the complex pathophysiology of Pendred syndrome. Abnormal ion transport in the inner ear explains the hearing and balance deficits, impaired iodide transport in the thyroid contributes to goiter formation, and renal and airway disturbances further illustrate the systemic implications of SLC26A4 mutations. Understanding these mechanisms is crucial for clinical management, including hearing rehabilitation, thyroid monitoring, metabolic evaluation, and respiratory care, as well as for informing genetic counseling and anticipatory guidance for affected families.

History and Physical

Patients with Pendred syndrome often present with minimal findings on personal and family history, and their initial physical examination may appear unremarkable. In many cases, a detailed family history may reveal early-onset or congenital hearing loss in siblings or extended relatives, although this is not universally observed due to the autosomal recessive inheritance pattern. Children born to carrier parents have a 25% chance of inheriting the condition, but many families may have no prior history of hearing impairment. The most frequent presenting complaint is early-onset hearing loss, which may be detected

during newborn hearing screening programs. In some patients, hearing deficits are identified later in infancy or early childhood during routine pediatric assessments or following concerns regarding delayed speech or language development [11]. Sensorineural hearing loss in Pendred syndrome varies widely, ranging from mild to profound. The condition is typically congenital or prelingual, although it may present later with progressive deterioration [8]. The hearing loss is usually bilateral, but asymmetry can occur. Exposure to acoustic trauma, barotrauma, or head injury can accelerate the progression of auditory deficits. Early clinical indicators include poor response to auditory stimuli, delayed acquisition of speech, or difficulties in verbal communication [1][8]. Vestibular manifestations are generally subtle and often overlooked during routine examinations. Children may display frequent falls, clumsiness, or difficulties with coordination, which reflect impaired balance function due to abnormal vestibular development [1]. Temporal bone anomalies are highly prevalent in Pendred syndrome, with enlargement of the vestibular aqueduct and Mondini malformation being common findings. These structural abnormalities are not detectable by physical examination alone and require imaging studies, such as high-resolution computed tomography (CT) or magnetic resonance imaging (MRI) of the temporal bone, for confirmation [7][12].

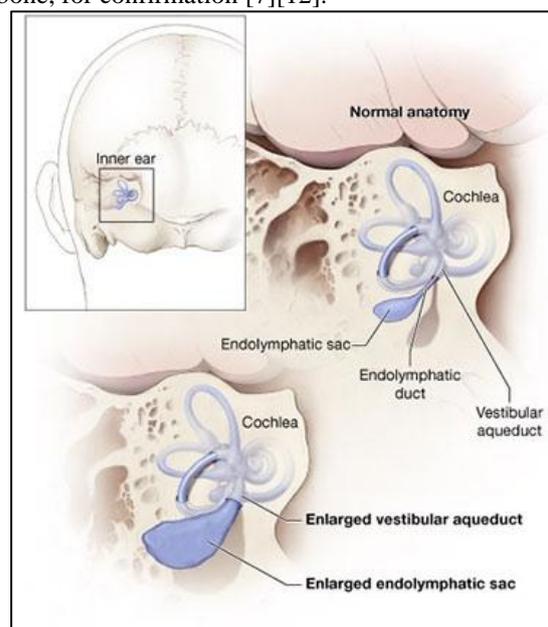


Fig. 1: Pendred Syndrome.

The thyroid gland is frequently affected in Pendred syndrome, with a euthyroid goiter representing the most common presentation [13]. Goiter may appear as a diffuse enlargement or as a multinodular growth, typically manifesting in late childhood, early puberty, or occasionally adulthood [1]. The underlying pathophysiology involves defects in iodide organification due to pendrin dysfunction, although many patients retain partial thyroid function

because iodide metabolism is not exclusively dependent on pendrin [13]. Approximately 75% of affected individuals develop a goiter detectable on physical examination [13]. In some patients, congenital thyroid enlargement is present, whereas others maintain normal thyroid size, particularly in regions with sufficient dietary iodine intake [1][8][13]. Thyroid function is variable; roughly half of patients remain euthyroid, while others develop subclinical or overt hypothyroidism, which may occasionally be congenital [1]. Regular thyroid assessment through palpation, serum thyroid hormone levels, and imaging is essential to monitor progression and guide management. Pendrin is expressed in the kidneys, where it regulates chloride reabsorption and bicarbonate secretion within type B and non-A non-B intercalated cells of the cortical collecting ducts. Dysfunction of pendrin can disrupt acid-base homeostasis, leading to metabolic alkalosis in some patients [10]. This complication can be severe and potentially life-threatening, highlighting the importance of monitoring electrolyte levels and acid-base status in individuals with Pendred syndrome. Clinical manifestations of renal involvement may be subtle initially but can include fatigue, muscle weakness, and increased susceptibility to electrolyte imbalances during periods of physiological stress. Early recognition of renal abnormalities allows timely intervention with electrolyte management and correction of acid-base disturbances, which is critical for preventing complications and maintaining overall homeostasis. Overall, the history and physical findings in Pendred syndrome are highly variable and often subtle in early childhood. Audiological deficits typically dominate the clinical picture, while thyroid and renal involvement may emerge gradually. Careful assessment, including detailed history taking, newborn and early childhood hearing screening, thyroid evaluation, and metabolic monitoring, is essential for the timely identification and management of this multisystem disorder. Multidisciplinary care involving audiologists, endocrinologists, nephrologists, and genetic counselors is recommended to optimize outcomes and improve quality of life for affected individuals [7][8][9].

Evaluation

The evaluation of Pendred syndrome requires a comprehensive, multidisciplinary approach combining audiologic, radiologic, laboratory, and genetic assessments. Early identification is crucial to guide management, monitor disease progression, and provide accurate genetic counseling for affected families. The complexity of Pendred syndrome stems from its multisystem involvement, variable phenotypic expression, and genetic heterogeneity, necessitating structured evaluation protocols tailored to each patient. Hearing loss is typically the earliest clinical manifestation of Pendred syndrome. Many infants are identified following failed newborn hearing screening, which often uses otoacoustic emissions.

While this screening is useful for detecting potential hearing deficits, its specificity is limited, and confirmatory testing is required [14]. Auditory brainstem response (ABR) testing is commonly employed in newborns and infants. ABR evaluates cochlear nerve function and auditory pathway integrity, providing objective measurements even in non-cooperative patients [14]. As children grow, assessment can include visual reinforced audiometry or conventional pure-tone audiometry, depending on cognitive and developmental readiness [15]. Vestibular evaluation is less routinely performed but can be considered in older children or those with reported imbalance, frequent falls, or clumsiness [16]. Temporal bone abnormalities, which often underlie vestibular dysfunction, cannot be detected on physical examination alone, reinforcing the need for targeted imaging in suspected cases. Imaging also serves as a predictive tool for hearing loss progression, as structural anomalies correlate with auditory deterioration [13].

Molecular testing of the SLC26A4 gene remains the definitive diagnostic tool for Pendred syndrome. Biallelic pathogenic variants in SLC26A4 confirm the diagnosis, while heterozygosity may indicate carrier status or partial penetrance [1][7][13]. The SLC26A4 gene exhibits substantial variability, with approximately 200 sequence variants identified. Less than 2% of cases are linked to mutations in FOXI1 or KCNJ10, highlighting the need for comprehensive analysis and targeted sequencing in patients with atypical presentations [7][13]. Genetic evaluation also informs family counseling, recurrence risk assessment, and reproductive planning, particularly in populations with high consanguinity rates. Clinicians should integrate genetic findings with phenotypic features to optimize diagnostic accuracy and resource utilization. High-resolution computed tomography (CT) of the temporal bone is the standard imaging modality to assess cochlear and vestibular anomalies. Enlargement of the vestibular aqueduct is the most consistent radiologic finding. Diagnostic criteria include the Valvassori criterion, defined as a midpoint width of the descending limb exceeding 1.5 mm, and the Cincinnati criterion, which considers a midpoint width greater than 1 mm and operculum width greater than 2 mm [13][17][18]. Additional inner ear anomalies, such as cochlear hypoplasia, are also identified on imaging. When cochlear hypoplasia coexists with vestibular aqueduct enlargement, the term Mondini malformation is applied [6][13]. Accurate identification of these anomalies is essential, as they correlate with disease severity and guide audiologic and surgical management.

Thyroid involvement in Pendred syndrome is primarily characterized by a euthyroid goiter. Physical examination may identify gland enlargement, but imaging modalities, particularly thyroid ultrasonography, provide precise volumetric assessment, nodule detection, and structural

characterization [1][13]. Laboratory testing of thyroid function, including measurement of serum thyroxine, triiodothyronine, and thyroid-stimulating hormone, is essential for baseline assessment and longitudinal monitoring. Pendred syndrome may coexist with autoimmune thyroiditis, which can complicate clinical management [1]. The perchlorate discharge test is a functional assay used to assess iodide organification defects. Following administration of radioactive iodine, retention of intrathyroidal radioactivity is measured, with a discharge exceeding 10% indicative of impaired organification [1][13]. However, this test is not entirely specific or sensitive; factors such as recent high-dose iodine exposure or partial pendrin activity can yield false-negative results. Consequently, the perchlorate discharge test is supplementary rather than diagnostic, and results should be interpreted in conjunction with genetic and imaging findings.

Professional guidelines emphasize a structured, multidisciplinary evaluation for patients with suspected Pendred syndrome. The American College of Medical Genetics and Genomics recommends genetic testing, comprehensive thyroid assessment, and temporal bone imaging as integral components of the diagnostic workup [19]. GeneReviews similarly underscores the importance of integrating audiologic, genetic, and endocrine evaluations to determine organ involvement, inform management strategies, and facilitate counseling for affected families [13]. Early diagnosis allows for timely hearing rehabilitation, balance therapy, and endocrine monitoring, which are essential to optimize functional outcomes and quality of life. Overall, evaluation of Pendred syndrome requires careful coordination across specialties. Audiologic testing identifies and quantifies hearing impairment, while vestibular assessments detect balance deficits. High-resolution imaging of the inner ear confirms structural anomalies and assists in prognostication. Thyroid evaluation, including functional testing and imaging, identifies goiter and subclinical dysfunction, supporting early intervention. Genetic testing provides definitive confirmation and informs family counseling. Comprehensive evaluation allows clinicians to develop individualized management plans, monitor disease progression, and implement preventive measures, ensuring optimal care for patients with this multisystem disorder. Multidisciplinary involvement, including audiologists, endocrinologists, radiologists, nephrologists, and genetic counselors, is essential for effective diagnosis, management, and long-term follow-up of individuals with Pendred syndrome.

Treatment and Management

The management of Pendred syndrome is primarily supportive and focuses on mitigating hearing loss, monitoring thyroid function, and preventing complications associated with multisystem involvement. Treatment strategies are individualized

based on the severity of clinical manifestations and the patient's developmental and functional needs. A multidisciplinary approach involving audiologists, endocrinologists, radiologists, and genetic counselors is essential to optimize outcomes and provide comprehensive care [13]. Hearing impairment is the most prominent feature of Pendred syndrome and requires early assessment and intervention. Audiologic evaluation should determine the degree and type of hearing loss, which can range from mild to profound and is often progressive. Management may involve the use of hearing aids for mild to moderate deficits, providing amplification and improving speech and language development [13][20]. In cases of severe to profound hearing loss, cochlear implantation is considered, as it can restore auditory perception and facilitate communication. Early intervention is particularly important for pediatric patients to prevent delays in language acquisition and cognitive development. Additionally, ongoing audiologic monitoring is recommended to detect progressive deterioration, especially after head trauma, barotrauma, or exposure to loud noise, which may accelerate hearing loss.

Thyroid involvement in Pendred syndrome is variable, with most patients presenting a euthyroid goiter. Regular monitoring of thyroid function through laboratory testing, including measurement of thyroid-stimulating hormone, free thyroxine, and triiodothyronine, is recommended every two to three years [13]. Subclinical or overt hypothyroidism, if detected, is managed with thyroid hormone replacement therapy tailored to the patient's age, weight, and clinical status. Goiter management requires careful assessment by an endocrinologist. Periodic thyroid ultrasound is used to monitor gland size and detect volumetric changes. Medical management may include thyroid hormone supplementation to reduce goiter size and suppress further growth. Surgical intervention is reserved for cases with compressive symptoms, cosmetic concerns, or suspicion of malignancy. Early recognition and intervention are critical to prevent complications associated with large or multinodular goiters [13]. Genetic counseling is a central component of Pendred syndrome management. Families of affected individuals should be informed about the autosomal recessive inheritance pattern, recurrence risks, and implications for future pregnancies. Genetic testing can identify at-risk family members and provide options for reproductive planning. Counseling supports informed decision-making and facilitates early diagnosis and intervention for siblings or offspring who may inherit the condition [13].

Patients are advised to avoid activities that may increase intracranial pressure or risk head trauma, including contact sports and heavy weightlifting, as these can exacerbate hearing loss or precipitate sudden deterioration. Educating patients and caregivers about

protective measures and safe activity choices is a key preventive strategy [13]. Research into targeted therapies for Pendred syndrome is ongoing. Novel small molecules, such as PC2-1, have demonstrated preclinical efficacy in restoring partial function to mutated pendrin proteins. These therapies offer potential for disease-modifying treatment, addressing the underlying molecular defect rather than solely managing symptoms. Although still experimental, such approaches may expand future management options and improve long-term outcomes for patients with Pendred syndrome [13][21]. Overall, management of Pendred syndrome emphasizes proactive monitoring, symptomatic treatment, and early intervention to optimize hearing, maintain thyroid function, and prevent complications. A coordinated, multidisciplinary approach ensures comprehensive care and enhances quality of life for affected individuals, while emerging therapies may provide opportunities for targeted molecular interventions in the future.

Differential Diagnosis

The differential diagnosis of Pendred syndrome requires careful consideration of both syndromic and nonsyndromic causes of hearing loss, as well as conditions that may affect the thyroid or inner ear. The clinical triad of sensorineural hearing impairment, goiter, and temporal bone malformations can overlap with multiple other disorders, making precise evaluation essential for accurate diagnosis and management. Comprehensive assessment typically involves detailed history taking, audiologic testing, imaging studies, thyroid evaluation, and, when indicated, molecular genetic analysis [13]. Nonsyndromic causes of hearing impairment must first be considered. Congenital infections, such as cytomegalovirus, can result in bilateral or unilateral sensorineural hearing loss and may present without other systemic manifestations. Exposure to ototoxic agents, including certain antibiotics or chemotherapeutic drugs, can also produce progressive or sudden hearing deficits. Traumatic injury to the ear or auditory pathway should be evaluated, particularly in children with a history of head trauma or perinatal complications. Additionally, nonsyndromic enlarged vestibular aqueduct (EVA) may mimic Pendred syndrome in terms of auditory findings but lacks associated thyroid pathology [13]. Congenital hypothyroidism with concurrent hearing impairment represents another nonsyndromic consideration, although thyroid hormone deficiencies are typically present early and can be detected through newborn screening programs [13].

Syndromic causes of hearing loss should also be systematically evaluated. Branchiootorenal (BOR) syndrome is characterized by branchial cleft anomalies, hearing impairment, and renal malformations, differentiating it from Pendred syndrome, which primarily involves thyroid and vestibular abnormalities [22]. Waardenburg syndrome

presents with pigmentary anomalies of the hair, skin, or eyes in addition to hearing loss, which provides a distinguishing feature [7][19]. Usher syndrome combines sensorineural hearing loss with progressive visual impairment due to retinitis pigmentosa, which is not observed in Pendred syndrome [19]. Alport syndrome involves hearing impairment, renal disease, and ocular abnormalities, overlapping with Pendred in auditory features but differing in renal pathology [7]. Jervell and Lange-Nielsen syndrome presents with profound congenital hearing loss and prolonged QT interval, highlighting the need for cardiac evaluation in suspected cases [7][19]. Perrault syndrome should also be considered in females, as it is characterized by progressive hearing loss and ovarian dysfunction [7][19]. Establishing a differential diagnosis relies on integrating clinical findings, audiologic profiles, imaging studies of the inner ear, and thyroid evaluation, alongside targeted genetic testing. Accurate differentiation ensures appropriate management, including hearing rehabilitation, endocrine monitoring, and counseling regarding recurrence risks, and prevents misdiagnosis that could delay interventions. Clinicians must maintain a high index of suspicion and systematically evaluate potential syndromic and nonsyndromic causes when patients present with hearing loss, vestibular dysfunction, or thyroid abnormalities.

Prognosis

The prognosis for Pendred syndrome is influenced by the severity of hearing loss, thyroid involvement, and structural abnormalities of the inner ear. Hearing impairment is the most prominent clinical feature, typically present at birth or during early childhood. Sensorineural hearing loss in Pendred syndrome is often progressive and may fluctuate, although the rate of deterioration varies among individuals. Early identification and intervention through hearing aids or cochlear implants can substantially improve auditory function, speech development, and overall communication, directly impacting quality of life. Consistent audiologic follow-up is essential to monitor changes in hearing and adjust interventions accordingly [1]. Thyroid function in affected individuals demonstrates considerable variability. Although goiter is a common manifestation, many patients maintain normal hormone levels, particularly in regions with adequate dietary iodine. When hypothyroidism develops, it is usually mild and effectively managed with standard hormone replacement therapy. Routine thyroid function testing and periodic ultrasound monitoring are recommended to detect changes in gland size or function early, enabling timely intervention and preventing complications [1]. Structural anomalies of the inner ear, including enlarged vestibular aqueducts and Mondini malformation, are characteristic of Pendred syndrome and contribute to both hearing and balance deficits. These malformations are generally stable and do not worsen over time. However, they

may complicate surgical interventions such as cochlear implantation, as altered cochlear anatomy requires specialized techniques and careful planning [23]. Vestibular symptoms, when present, are typically mild and can be managed with physical therapy or balance rehabilitation. With timely and coordinated care—including audiologic support, thyroid monitoring, genetic counseling, and management of vestibular symptoms—individuals with Pendred syndrome can achieve functional independence and maintain a good quality of life. Long-term follow-up is crucial for monitoring disease progression, addressing new complications, and ensuring that therapeutic strategies remain effective throughout childhood and adulthood.

Complications

Pendred syndrome is associated with a range of complications that reflect its multisystem involvement, primarily affecting the auditory, endocrine, and vestibular systems, with occasional renal and metabolic manifestations. Sensorineural hearing loss is the most significant complication and can present at birth or emerge in early childhood. The severity of hearing impairment varies from mild to profound, and the condition is often progressive. Fluctuating hearing thresholds are common, which may be exacerbated by head trauma or exposure to acoustic or barometric stressors. Untreated or poorly managed hearing loss can have profound consequences on speech, language development, educational attainment, and overall quality of life. Early intervention with hearing aids or cochlear implants can mitigate these effects and improve communication, but ongoing audiologic follow-up is essential to monitor changes and adjust interventions as necessary [1][13]. Thyroid dysfunction represents another important complication. Goiter, typically developing during late childhood or adolescence, is the most frequent manifestation. While many patients maintain normal thyroid hormone levels, some develop hypothyroidism, which can range from subclinical forms to overt hormone deficiency requiring replacement therapy. Untreated hypothyroidism may lead to additional metabolic or cardiovascular complications. Regular thyroid monitoring, including laboratory testing and ultrasound evaluation, is necessary to detect and manage changes in gland function or size promptly [1][13]. Structural abnormalities of the inner ear, including enlarged vestibular aqueducts and Mondini malformations, contribute not only to hearing impairment but also to vestibular dysfunction. Children may experience frequent falls, clumsiness, or difficulty with balance, which can affect daily activities and participation in sports or physical education. These malformations can also complicate surgical interventions, such as cochlear implantation, due to altered cochlear anatomy [13][23].

Renal and metabolic complications are less common but clinically significant. Pendrin dysfunction in the kidneys can impair bicarbonate secretion and chloride reabsorption, potentially leading to metabolic alkalosis [10]. This condition may become severe if exacerbated by dietary or physiological stressors. Rarely, Pendred syndrome has been reported in association with Hoffmann syndrome, a form of hypothyroid myopathy characterized by muscle weakness, stiffness, pseudohypertrophy, and delayed tendon reflexes [24]. This association emphasizes the potential for systemic complications in cases of longstanding or inadequately treated thyroid dysfunction. Beyond physical complications, Pendred syndrome can impact psychosocial development. Hearing and balance difficulties may affect academic performance, social interactions, and future employment opportunities. Chronic disease management and repeated medical evaluations can contribute to stress, anxiety, and reduced quality of life, underscoring the need for comprehensive medical and supportive care. Multidisciplinary intervention, including audiology, endocrinology, physical therapy, and counseling, is critical to prevent or mitigate these complications and optimize long-term outcomes for affected individuals.

Patient Education

Patients with Pendred syndrome should receive comprehensive education about the genetic, clinical, and management aspects of the condition. It is essential to explain that Pendred syndrome is an inherited disorder, caused primarily by mutations in the SLC26A4 gene, which encodes the pendrin protein responsible for transporting chloride, iodide, and bicarbonate ions within the inner ear, thyroid, and kidneys [13]. Emphasis should be placed on the characteristic triad of the syndrome: sensorineural hearing loss, thyroid abnormalities such as goiter or hypothyroidism, and inner ear malformations, including enlarged vestibular aqueducts or Mondini malformations. Patients and caregivers should understand that hearing loss is typically present at birth or develops during early childhood, may be progressive, and often affects both ears. Early detection through newborn hearing screening and formal audiologic evaluation is critical. Intervention strategies, including hearing aids or cochlear implants, should be discussed along with the importance of ongoing speech therapy and educational support to optimize communication skills and learning outcomes [13]. Thyroid involvement may be asymptomatic initially, with goiter developing in late childhood or early adulthood. Patients should be educated about the need for periodic thyroid function testing and monitoring with ultrasound, as hypothyroidism can develop even in previously euthyroid individuals. Early recognition and treatment with hormone replacement therapy can prevent complications and support normal growth and development [13].

Counseling should also include guidance on activity modification. Patients should avoid activities that risk sudden head trauma or rapid increases in intracranial pressure, such as contact sports or heavy weightlifting, as these can accelerate hearing deterioration. Families should be informed about the autosomal recessive inheritance pattern of Pendred syndrome and the role of genetic counseling in assessing recurrence risk and planning future pregnancies. Education should be ongoing, personalized, and involve clear communication regarding the importance of regular medical follow-up, adherence to interventions, and monitoring of emerging symptoms to ensure optimal long-term outcomes.

Other Issues

Key points about Pendred syndrome provide essential guidance for patients, caregivers, and healthcare providers. Mutations in the SLC26A4 gene are the primary cause, affecting pendrin, which regulates chloride, iodide, and bicarbonate transport throughout the body. Hearing loss is often the first sign and typically appears at birth or in early childhood. It can range from moderate to profound and is frequently associated with inner ear abnormalities, most notably an enlarged vestibular aqueduct or Mondini malformation, which can contribute to balance difficulties [13]. Thyroid involvement usually presents as a goiter during late childhood or early adulthood. Most patients maintain normal thyroid hormone levels, but hypothyroidism can occur and requires timely monitoring and, if needed, hormone replacement therapy. Vestibular dysfunction may manifest as balance problems or frequent falls, particularly in children, and can be addressed through physical therapy and coordination training [13]. Diagnostic evaluation relies on genetic testing to confirm SLC26A4 mutations. A perchlorate discharge test may be used to assess thyroid iodide organification, supporting diagnosis if positive. Imaging studies, particularly high-resolution CT of the temporal bone, can reveal vestibular aqueduct enlargement or other cochlear malformations, providing essential information for prognosis and surgical planning [13]. Management emphasizes early intervention. Hearing aids or cochlear implants are vital for auditory rehabilitation, supported by speech therapy and educational accommodations. Thyroid monitoring should occur regularly, with hormone treatment implemented as needed. Physical therapy can improve coordination and reduce the risk of falls. Patients and families should understand that early recognition, consistent follow-up, and adherence to management strategies are key to maintaining quality of life, supporting academic and social development, and achieving optimal long-term outcomes.

Enhancing Healthcare Team Outcomes

Effective management of Pendred syndrome requires a coordinated interprofessional approach that integrates multiple specialties. Key team members include otolaryngologists, audiologists,

endocrinologists, geneticists, radiologists, and surgeons, each contributing to diagnosis, treatment planning, and long-term monitoring. Collaboration among these professionals ensures that patients receive comprehensive care addressing hearing impairment, thyroid function, vestibular disturbances, and potential metabolic complications. Nurses play a critical role within this team, providing direct patient care, education, and coordination. In surgical cases, perioperative nurses assist with preparation, intraoperative support, and postoperative monitoring, ensuring patient safety and adherence to protocols. Postoperative nurses manage pain control, monitor for complications, and provide guidance on activity restrictions, wound care, and rehabilitation. They also act as patient advocates, ensuring that concerns are communicated promptly to the broader team. Beyond surgical care, nurses contribute to chronic disease management by monitoring hearing and thyroid function, facilitating follow-up appointments, and reinforcing adherence to prescribed treatments. They educate patients and families on recognizing early signs of complications, safe activity modifications, and proper use of hearing devices or cochlear implants. Nurses also support psychosocial aspects of care, addressing anxiety, promoting coping strategies, and connecting families with community or educational resources. Open communication among all members of the healthcare team is essential. Nurses often serve as the central point of contact, coordinating between specialists and ensuring continuity of care. Their active involvement in patient assessment, education, and advocacy enhances clinical outcomes, minimizes complications, and improves quality of life for individuals with Pendred syndrome. By integrating nursing expertise into the interprofessional team, healthcare providers can deliver holistic, patient-centered care that addresses both medical and psychosocial needs [20][21].

Conclusion:

Pendred syndrome presents a complex clinical picture involving auditory, thyroid, vestibular, and occasionally renal systems, requiring vigilant assessment and lifelong monitoring. Hearing loss remains the most prominent and impactful feature, often beginning at birth or early childhood and progressing with age or following minor trauma. Early rehabilitation through hearing aids or cochlear implantation is essential for preserving communication abilities and supporting normal language and cognitive development. Thyroid involvement, particularly euthyroid goiter, emerges during later childhood or adolescence. Although many patients maintain normal thyroid hormone levels, regular evaluation is critical to identify emerging hypothyroidism, which is effectively treated with hormone replacement therapy. Inner ear malformations contribute to both hearing and balance dysfunction, and their recognition is crucial for clinical planning, especially when surgical

interventions such as cochlear implantation are considered. A multidisciplinary approach incorporating audiology, endocrinology, radiology, genetics, and nursing ensures comprehensive care, timely interventions, and optimal long-term outcomes. Nurses serve as essential coordinators, educators, and advocates, reinforcing adherence, monitoring for complications, and supporting psychosocial well-being. With early identification, consistent follow-up, and patient-centered management, individuals with Pendred syndrome can achieve functional independence and maintain a good quality of life across the lifespan.

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