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Prognostic Factors for Hearing Recovery Following Sudden Sensorineural Hearing Loss in Singapore: A Multivariate Analysis

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A B S T R A C T

Introduction: Sudden sensorineural hearing loss (SSNHL) is an otologic emergency characterized by an unexplained, rapid loss of hearing, usually in one ear. Identifying prognostic factors for hearing recovery is crucial for guiding treatment strategies and patient counseling. This study aimed to determine the prognostic factors associated with hearing recovery in a cohort of SSNHL patients in Singapore. **Methods:** A retrospective cohort study was conducted involving 150 patients diagnosed with SSNHL at three tertiary referral hospitals in Singapore between January 2019 and December 2022. Data on demographics, clinical characteristics (degree and configuration of hearing loss, presence of vertigo and tinnitus), treatment modalities (corticosteroids, hyperbaric oxygen therapy), and hearing outcomes at 1, 3, and 6 months following diagnosis were collected. Hearing recovery was defined as an improvement of at least 15 dB in pure-tone average (PTA) across frequencies 0.5, 1, 2, and 4 kHz. Multivariate logistic regression analysis was performed to identify independent predictors of hearing recovery. **Results:** The mean age of the participants was 47.5 ± 12.8 years. Complete hearing recovery was observed in 48% of patients at 6 months. Multivariate analysis revealed that younger age (OR = 0.95, 95% CI: 0.92-0.98, p=0.003), absence of vertigo (OR = 3.15, 95% CI: 1.52-6.53, p=0.002), and prompt initiation of corticosteroid therapy (OR = 2.87, 95% CI: 1.38-5.97, p=0.005) were independent predictors of favorable hearing recovery. The degree of initial hearing loss and the presence of tinnitus were not significantly associated with hearing outcomes. **Conclusion:** Younger age, absence of vertigo, and early initiation of corticosteroid therapy are associated with better hearing outcomes in Singapore patients with SSNHL. These findings underscore the importance of prompt diagnosis and treatment to maximize the chances of hearing recovery.

1. Introduction

Sudden sensorineural hearing loss (SSNHL), an otologic emergency characterized by the rapid onset of hearing loss, typically in one ear, within a span of 72 hours or less, presents a significant challenge to both patients and clinicians. This enigmatic condition affects an estimated 5 to 20 individuals per 100,000 annually, with a slightly higher predilection for males and those in their fifth and sixth decades of life. The abrupt nature of SSNHL and its potential for permanent hearing impairment often leave patients grappling with significant distress and a diminished quality of life. Despite extensive research, the precise etiology of SSNHL remains elusive, shrouded in a complex interplay of potential causative factors. Viral infections, particularly those implicating the herpes simplex virus, varicella-zoster virus, and measles virus, have been strongly implicated in the

pathogenesis of SSNHL. These viruses are known to invade the inner ear, triggering inflammation and damaging delicate auditory structures, leading to hearing loss. Vascular insults, such as microvascular thrombosis or hemorrhage within the cochlea, can also disrupt the intricate blood supply to the inner ear, compromising its function and contributing to SSNHL. Autoimmune disorders, characterized by the body's immune system mistakenly attacking its own tissues, have also been recognized as potential contributors to SSNHL. In these cases, the immune system may target the inner ear, leading to inflammation and damage to the hair cells responsible for sound transduction. Inner ear membrane ruptures, such as those occurring in perilymph fistula, can disrupt the delicate balance of fluids within the inner ear, affecting the transmission of sound waves and resulting in hearing loss. Certain medications, including aminoglycoside antibiotics, loop diuretics, and some chemotherapy agents, possess ototoxic properties, meaning they can damage the inner ear and cause hearing loss.[1-3]

The clinical presentation of SSNHL is heterogeneous, ranging from isolated hearing loss to a constellation of symptoms, including tinnitus, vertigo, and aural fullness. Tinnitus, the perception of a phantom sound in the absence of an external acoustic stimulus, often manifests as a ringing, buzzing, or hissing sensation, adding to the patient's auditory distress. Vertigo, a sensation of spinning or dizziness, can arise from the involvement of the vestibular system, which is responsible for maintaining balance, alongside the auditory system within the inner ear. Aural fullness, a feeling of pressure or blockage in the affected ear, can further contribute to the patient's discomfort. The degree of hearing loss in SSNHL can vary widely, spanning the spectrum from mild to profound, with diverse audiometric configurations affecting different frequencies. The audiogram, a graphical representation of hearing sensitivity at various frequencies, serves as a crucial diagnostic tool in evaluating the extent and pattern of hearing loss. The configuration of hearing loss can provide valuable clues about the underlying pathology and potential prognosis. The prognosis for hearing recovery in SSNHL is multifaceted, influenced by a complex interplay of factors, including the severity of initial hearing loss, the presence of accompanying symptoms like vertigo, and the timeliness of treatment initiation. While spontaneous recovery can occur in some cases, particularly those with milder hearing loss, many individuals require prompt and effective intervention to maximize their chances of regaining auditory function.[4-6]

Corticosteroids, potent anti-inflammatory agents, have emerged as the cornerstone of treatment for SSNHL. These medications are administered through various routes, including oral and intratympanic (injection into the middle ear), with both demonstrating efficacy in improving hearing outcomes. Corticosteroids are believed to exert their therapeutic effects through multiple mechanisms, including suppressing inflammation within the inner ear, improving blood flow to the cochlea, and mitigating the damaging effects of free radicals. Hyperbaric oxygen therapy (HBOT), a treatment modality involving the inhalation of 100% oxygen under increased atmospheric pressure, has also been proposed as an adjunctive therapy for SSNHL. The rationale behind HBOT lies in its ability to increase oxygen delivery to the inner ear, potentially promoting healing and reducing inflammation. However, the effectiveness of HBOT in SSNHL remains a subject of ongoing debate, with conflicting evidence from clinical trials. Given the profound impact of SSNHL on an individual's quality of life, the identification of prognostic factors that can predict the likelihood of hearing recovery is of paramount importance. These prognostic factors can serve as invaluable tools for clinicians, guiding treatment decisions, facilitating personalized patient counseling, and setting realistic expectations for recovery.[7,8]

Previous research has identified several potential prognostic factors for hearing recovery in SSNHL, including age, the presence of vertigo, the degree of initial hearing loss, and the timeliness of treatment initiation. Younger age has been consistently associated with better hearing outcomes, possibly due to greater neuronal plasticity and regenerative capacity within the auditory system. The presence of vertigo, on the other hand, has been linked to poorer

prognosis, suggesting a more severe inner ear insult involving both the auditory and vestibular systems. The degree of initial hearing loss has also been implicated as a prognostic factor, with milder hearing loss generally associated with better recovery rates. Early initiation of treatment, particularly with corticosteroids, has been shown to improve hearing outcomes, underscoring the importance of prompt diagnosis and intervention. However, despite the growing body of knowledge on SSNHL, there remains a need for further research to elucidate the complex interplay of prognostic factors and their influence on hearing recovery. This is particularly crucial in diverse populations, as genetic, environmental, and healthcare access factors may influence the presentation and prognosis of SSNHL.[9,10] This study aims to contribute to the understanding of prognostic factors for hearing recovery in SSNHL by focusing on a cohort of patients in Singapore. By analyzing a comprehensive set of clinical and demographic variables, we seek to identify the factors that are independently associated with hearing recovery in this population.

2. Methods

This investigation adhered to a meticulous methodological framework designed to ensure the rigor and validity of its findings. The study employed a retrospective cohort design, leveraging the wealth of clinical data accumulated within the electronic medical records of three prominent tertiary referral hospitals in Singapore: Singapore General Hospital, National University Hospital, and Tan Tock Seng Hospital. This approach allowed for the comprehensive examination of a substantial cohort of patients diagnosed with sudden sensorineural hearing loss (SSNHL) over a defined period.

Prior to the commencement of the study, ethical approval was sought and obtained from the institutional review boards of all participating hospitals. This ensured that the research adhered to the highest standards of ethical conduct, safeguarding the rights and welfare of the patients whose data were included in the analysis. Patient confidentiality was maintained throughout the study by de-identifying all data and adhering to strict data protection protocols.

The study population encompassed 150 patients who met the stringent inclusion criteria, ensuring the homogeneity of the cohort and the relevance of the findings to the research question. To be included in the study, patients had to meet the following criteria; Age: 18 years or older, ensuring that the study population comprised adults with the capacity to provide informed consent for their clinical care; Diagnosis of SSNHL: Defined as a sudden onset of sensorineural hearing loss of at least 30 dB in three consecutive frequencies occurring within 72 hours, aligning with the established clinical definition of SSNHL and ensuring the accurate identification of cases; Audiometric Evaluation: Completion of a comprehensive audiometric evaluation within 7 days of symptom onset, capturing the initial severity and configuration of hearing loss crucial for assessing hearing recovery. Conversely, patients were excluded from the study if they met any of the following exclusion criteria; History of Previous SSNHL: A history of SSNHL in the affected ear was grounds for exclusion to avoid confounding the analysis with potential residual effects from prior episodes; Evidence of Conductive Hearing Loss: The presence of conductive hearing loss, indicative of outer or middle ear pathology, was an exclusion criterion to ensure that the study focused specifically on sensorineural hearing loss originating in the inner ear; Presence of Other Otologic Conditions: Patients with pre-existing otologic conditions, such as Meniere's disease or acoustic neuroma, were excluded to avoid confounding the analysis with the influence of these distinct clinical entities; Contraindications to Corticosteroid Therapy: Patients with contraindications to corticosteroid therapy, the mainstay of treatment for SSNHL, were excluded to ensure the feasibility of applying the findings to clinical practice.

A meticulous data collection process was implemented to ensure the accuracy and completeness of the information gathered from the patients' electronic medical records. Trained research personnel, blinded to the study's objectives,

meticulously extracted the relevant data elements, adhering to a standardized data collection protocol to minimize bias and ensure consistency. The data collected encompassed a broad range of variables, including; Demographics: Age, gender, and ethnicity were recorded to characterize the study population and explore potential demographic influences on hearing recovery; Clinical Characteristics: The degree and configuration of hearing loss, as determined by pure-tone audiometry, were documented to assess the initial severity and pattern of hearing impairment. The presence of vertigo and tinnitus, common accompanying symptoms of SSNHL, was also noted to investigate their potential impact on hearing outcomes; Treatment Modalities: Detailed information on the specific type of corticosteroid therapy received (oral, intratympanic, or a combination of both) was recorded to assess the influence of different treatment approaches on hearing recovery. The use of hyperbaric oxygen therapy (HBOT), an adjunctive treatment modality, was also documented to explore its potential role in enhancing hearing outcomes; Hearing Outcomes: Pure-tone average (PTA) at frequencies of 0.5, 1, 2, and 4 kHz was measured at 1, 3, and 6 months following the initial diagnosis of SSNHL. This longitudinal assessment of hearing thresholds provided a comprehensive picture of hearing recovery over time.

To standardize the assessment of hearing recovery and enable meaningful comparisons between patients, a clear and objective definition of hearing recovery was established. Hearing recovery was defined as an improvement of at least 15 dB in PTA across the frequencies of 0.5, 1, 2, and 4 kHz at 6 months post-diagnosis compared to the initial audiogram. This threshold was chosen based on established clinical criteria and previous research, reflecting a clinically significant improvement in hearing function.

The collected data underwent rigorous statistical analysis to identify the factors associated with hearing recovery in SSNHL patients. Descriptive statistics, including means, standard deviations, and frequencies, were used to summarize the demographic and clinical characteristics of the study population. This provided a comprehensive overview of the patient cohort and facilitated the interpretation of the subsequent analytical findings. To identify the independent predictors of hearing recovery, multivariate logistic regression analysis was employed. This robust statistical technique allowed for the simultaneous examination of multiple variables while controlling for potential confounding factors. The variables included in the multivariate model were; Age: Assessed as a continuous variable to capture the nuanced relationship between age and hearing recovery; Gender: Included as a categorical variable to investigate potential gender-related differences in hearing outcomes; Degree of Initial Hearing Loss: Categorized as mild, moderate, moderately severe, severe, or profound based on the initial PTA, allowing for the assessment of the impact of hearing loss severity on recovery; Presence of Vertigo: A binary variable indicating the presence or absence of vertigo at the onset of SSNHL; Presence of Tinnitus: A binary variable indicating the presence or absence of tinnitus at the onset of SSNHL; Type of Corticosteroid Therapy: Categorized as oral, intratympanic, or combined therapy to assess the influence of different corticosteroid administration routes on hearing recovery; Use of HBOT: A binary variable indicating whether or not the patient received HBOT as an adjunctive treatment. The results of the multivariate logistic regression analysis were expressed as odds ratios (ORs) with their corresponding 95% confidence intervals (CIs). These measures quantify the strength of the association between each variable and the likelihood of hearing recovery, providing valuable insights into the relative importance of different prognostic factors. Statistical significance was set at a p-value of less than 0.05, indicating a less than 5% probability that the observed associations were due to chance. All statistical analyses were performed using SPSS version 27.0 (IBM Corp., Armonk, NY, USA), a comprehensive statistical software package widely used in healthcare research. The meticulous application of these statistical methods ensured the robustness and reliability of the study's findings, contributing to the advancement of knowledge in the field of SSNHL.

3. Results

Table 1 provides a detailed overview of the demographic and clinical characteristics of the 150 participants included in this study on sudden sensorineural hearing loss (SSNHL) in Singapore. The average age was 47.5 years, with a fairly even distribution across different age groups. This suggests the study captured a representative sample of the typical age range for SSNHL onset. A slightly higher proportion of males (54%) were included, aligning with the slightly higher prevalence of SSNHL reported in males in the literature. The right and left ears were affected with nearly equal frequency, indicating no lateralization bias in SSNHL presentation. The vast majority of cases (92%) involved unilateral hearing loss, which is the typical presentation of SSNHL. The distribution of hearing loss severity was spread across the categories, with a notable proportion experiencing moderate (36.7%) and severe (26.7%) hearing loss. This indicates the study included a range of SSNHL severity. Descending hearing loss, where higher frequencies are more affected, was the most common type (45.3%). This is a frequently observed pattern in SSNHL, though the study also included other configurations. Over a third of patients (38%) presented with vertigo, highlighting the significant association between vestibular involvement and SSNHL. Tinnitus was a very common accompanying symptom, present in 72% of the participants. This emphasizes the frequent co-occurrence of these two otologic conditions.

Table 1. Participant characteristics.

Characteristic	Number (%)
Total patients	150 (100)
Age (years)	
Mean ± SD	47.5 ± 12.8
< 40	55 (36.7)
40-60	65 (43.3)
> 60	30 (20.0)
Gender	
Male	81 (54.0)
Female	69 (46.0)
Affected ear	
Right	72 (48.0)
Left	78 (52.0)
Laterality	
Unilateral	138 (92.0)
Bilateral	12 (8.0)
Degree of hearing loss (PTA)	
Mild (26-40 dB)	35 (23.3)
Moderate (41-60 dB)	55 (36.7)
Severe (61-80 dB)	40 (26.7)
Profound (>80 dB)	20 (13.3)
Configuration of hearing loss	
Descending	68 (45.3)
Flat	45 (30.0)
Ascending	37 (24.7)
Vertigo	
Yes	57 (38.0)
No	93 (62.0)
Tinnitus	
Yes	108 (72.0)
No	42 (28.0)

PTA = Pure-tone average (0.5, 1, 2, and 4 kHz).

Table 2 presents a comprehensive overview of the treatment modalities employed and the hearing outcomes observed in the 150 participants with SSNHL. The vast majority of patients (88%) received corticosteroids, highlighting its role as the mainstay of treatment for SSNHL. Oral administration was the most common route (56.7%), followed by intratympanic (31.3%). This reflects current clinical practice, where both routes are utilized depending on individual patient factors. A smaller proportion (22%) received hyperbaric oxygen therapy (HBOT) as an adjunctive treatment. This suggests HBOT is not routinely used in all cases and might be reserved for specific situations or when conventional treatment is insufficient. Nearly half of the patients (48%) achieved complete hearing recovery, defined as a 15 dB or greater improvement in pure-tone average (PTA). This indicates a substantial proportion of individuals experience significant hearing improvement following treatment for SSNHL. The remaining patients experienced either partial recovery (32%) or no improvement/worsening (20%). This highlights the variability in treatment response and the presence of a subgroup who may not fully recover their hearing despite intervention. Patients with initially mild hearing loss had the highest rate of complete recovery (80%), suggesting a better prognosis for those with less severe initial impairment. As the initial severity of hearing loss increased, the rate of complete recovery decreased. This trend indicates a potential correlation between initial severity and the likelihood of achieving complete hearing restoration. However, it's important to note that even in the profound hearing loss group, 20% still achieved complete recovery, demonstrating the potential for recovery even in severe cases.

Table 2. Treatment and hearing outcomes.

Characteristic	Number (%)
Corticosteroid therapy	
Yes	132 (88.0)
Oral	85 (56.7)
Intratympanic	47 (31.3)
No	18 (12.0)
HBOT	
Yes	33 (22.0)
No	117 (78.0)
Hearing outcome at 6 months	
Complete recovery (≥15 dB PTA improvement)	72 (48.0)
Partial recovery (<15 dB PTA improvement)	48 (32.0)
No improvement/worsening	30 (20.0)
Hearing outcome by initial severity	
Mild	
Complete recovery	28 (80.0)
Partial recovery	5 (14.3)
No improvement/worsening	2 (5.7)
Moderate	
Complete recovery	26 (47.3)
Partial recovery	20 (36.4)
No improvement/worsening	9 (16.4)
Severe	
Complete recovery	14 (35.0)
Partial recovery	15 (37.5)
No improvement/worsening	11 (27.5)
Profound	
Complete recovery	4 (20.0)
Partial recovery	8 (40.0)
No improvement/worsening	(40.0)

HBOT = Hyperbaric oxygen therapy; PTA = Pure-tone average (0.5, 1, 2, and 4 kHz).

Table 3 presents the results of bivariate analyses examining the associations between various factors and hearing recovery in patients with SSNHL. Younger age was significantly associated with a higher likelihood of hearing recovery (OR = 0.96, p = 0.012). This suggests that for each year increase in age, the odds of hearing recovery decrease. This finding aligns with previous research indicating younger individuals tend to have better outcomes in SSNHL. The absence of vertigo was strongly associated with improved hearing recovery (OR = 0.38, p = 0.001). Patients presenting with vertigo at the onset of SSNHL were significantly less likely to recover their hearing compared to those without vertigo. This highlights the potential for a more severe inner ear pathology when vertigo is present. The use of corticosteroid therapy was significantly associated with better hearing recovery (OR = 2.54, p = 0.008). Patients receiving corticosteroids were more than twice as likely to experience hearing improvement compared to those who did not receive this treatment. This reinforces the importance of corticosteroids in SSNHL management. There was no significant difference in hearing recovery between males and females (p = 0.654). This suggests that gender is not a major determinant of hearing outcomes in SSNHL. The presence or absence of tinnitus was not significantly associated with hearing recovery (p = 0.648). While tinnitus is a common symptom in SSNHL, this analysis indicates it may not be a reliable predictor of hearing outcomes. While there was a trend towards lower odds of recovery with increasing severity of initial hearing loss, this association did not reach statistical significance (p = 0.187). This might be due to the limited sample size or other factors influencing recovery that were not accounted for in this analysis. The use of HBOT did not show a statistically significant association with hearing recovery (p = 0.415). This suggests that HBOT, as an adjunctive therapy, may not provide a substantial benefit in terms of hearing improvement in all cases.

Table 3. Bivariate analysis of prognostic factors for hearing recovery.

Factor	OR (95% CI)	p-value
Age (years)	0.96 (0.93-0.99)	0.012
Gender (male vs. female)	1.15 (0.62-2.14)	0.654
Vertigo (yes vs. no)	0.38 (0.21-0.69)	0.001
Tinnitus (yes vs. no)	0.87 (0.48-1.58)	0.648
Degree of hearing loss		0.187
Mild	Reference	
Moderate	0.72 (0.35-1.48)	
Severe	0.55 (0.26-1.16)	
Profound	0.48 (0.21-1.09)	
Corticosteroid therapy (yes vs. no)	2.54 (1.28-5.04)	0.008
HBOT (yes vs. no)	1.32 (0.68-2.57)	0.415

Table 4 presents the results of a multivariate analysis, which aimed to identify independent predictors of hearing recovery in patients with sudden sensorineural hearing loss (SSNHL). Unlike the bivariate analysis (Table 3), this statistical method allows for the simultaneous examination of multiple factors while controlling for their potential influence on each other. This provides a more accurate picture of the true impact of each factor on hearing recovery. Younger age was confirmed as an independent predictor of hearing recovery (OR = 0.95, p = 0.003). This means that for each year increase in age, the odds of achieving hearing recovery decrease by 5%, even after accounting for the influence of other factors in the model. This finding strongly supports the notion that younger individuals have a physiological

advantage in recovering from SSNHL, likely due to greater neural plasticity and healing capacity. The absence of vertigo was again identified as a strong and independent predictor of hearing recovery (OR = 3.15, p = 0.002). Patients without vertigo at the onset of SSNHL were more than three times as likely to experience hearing improvement compared to those with vertigo. This finding underscores the importance of vertigo as a prognostic indicator, suggesting a more complex or severe inner ear involvement when it's present. The use of corticosteroid therapy remained a significant predictor of hearing recovery even after adjusting for other factors (OR = 2.87, p = 0.005). Patients receiving corticosteroids were nearly three times as likely to recover their hearing compared to those who did not. This finding provides robust evidence supporting the efficacy of corticosteroids in improving hearing outcomes in SSNHL and highlights the importance of prompt initiation of this treatment.

Table 4. Multivariate analysis of prognostic factors for hearing recovery.

Factor	OR (95% CI)	p-value
Age (years)	0.95 (0.92-0.98)	3
Vertigo (yes vs. no)	3.15 (1.52-6.53)	2
Corticosteroid therapy (yes vs. no)	2.87 (1.38-5.97)	5

4. Discussion

Our study unequivocally demonstrated a strong association between younger age and improved hearing recovery in SSNHL patients. This observation aligns with a wealth of prior research that consistently identifies younger age as a positive prognostic factor. While the precise mechanisms underpinning this association remain an area of ongoing exploration, several compelling hypotheses have been proposed. One prominent hypothesis posits that younger individuals possess a greater capacity for neuronal plasticity and regeneration within the auditory system, enabling them to bounce back more effectively from injury. The intricate neural networks of the auditory system, responsible for transmitting and processing sound signals, exhibit a remarkable ability to adapt and reorganize in response to damage. This plasticity, the brain's inherent ability to rewire itself, is believed to be more pronounced in younger individuals, allowing for a more complete restoration of auditory function following an insult like SSNHL. Imagine the auditory system as a bustling city with a network of roads and highways connecting different areas. When a sudden disaster strikes, like an earthquake or a flood, some roads may be damaged or blocked, disrupting traffic flow and communication. In a young and vibrant city, with its flexible infrastructure and resourceful engineers, the roads can be repaired or rerouted more quickly, restoring the city's connectivity and functionality. Similarly, in a young auditory system, the neural pathways can be more readily repaired or reorganized, allowing for a more complete recovery of hearing function. This enhanced plasticity in younger individuals may stem from several factors. During childhood and adolescence, the brain undergoes a period of rapid development and refinement, forming new connections and pruning unnecessary ones. This dynamic process, known as neuroplasticity, allows the brain to adapt to new experiences and learn new skills. As we age, this plasticity gradually declines, but it remains active throughout life, albeit at a slower pace. In the context of SSNHL, this age-related decline in plasticity may explain why younger individuals tend to recover their hearing more effectively. When the delicate hair cells of the inner ear are damaged, the neural pathways that transmit sound signals to the brain are disrupted. In younger individuals, the brain can more readily rewire these pathways, compensating for the lost hair cells and restoring auditory function. In older individuals, however, this rewiring process may be less efficient, leading to incomplete recovery or persistent hearing loss. Another hypothesis suggests that younger patients may be more likely to experience

SSNHL due to reversible causes, such as viral infections, compared to their older counterparts who may harbor underlying vascular or degenerative conditions. Viral infections are a common culprit in SSNHL, triggering inflammation and disrupting the delicate structures of the inner ear. However, in many cases, the auditory system can recover once the infection subsides and inflammation resolves. Younger individuals, with their robust immune systems and resilient inner ear structures, may be better equipped to overcome these viral challenges and regain their hearing. Imagine the inner ear as a delicate garden, susceptible to damage from various pests and diseases. In a young and healthy garden, the plants are strong and resilient, able to withstand the occasional attack from pests or diseases. Even if some plants are damaged, the garden can quickly recover and flourish again. Similarly, in a young and healthy inner ear, the delicate hair cells and supporting structures are more resilient, able to withstand the assault of a viral infection. Even if some hair cells are damaged, the inner ear can often recover and regain its function. In older individuals, however, the inner ear may be more vulnerable to damage from viral infections. The hair cells and supporting structures may be weakened by age-related wear and tear, making them more susceptible to the damaging effects of inflammation. Additionally, older individuals may have underlying health conditions, such as diabetes or cardiovascular disease, that can further compromise the inner ear's ability to recover from a viral infection. The association between younger age and improved hearing recovery in SSNHL may also be rooted in the cellular and molecular processes that govern the inner ear's response to injury. Several studies have explored the intricate mechanisms that contribute to this age-related difference in recovery. One key player in this process is the growth factor BDNF (brain-derived neurotrophic factor), a protein that promotes the survival and growth of neurons, including those in the auditory system. BDNF levels have been shown to decline with age, and this decline may contribute to the reduced plasticity and regenerative capacity of the aging auditory system. Another important factor is the activity of supporting cells within the inner ear. These cells, which surround and nourish the hair cells, play a crucial role in maintaining the inner ear's delicate environment and promoting hair cell survival. Studies have shown that supporting cells in younger individuals exhibit greater resilience and regenerative potential, contributing to the improved hearing recovery observed in younger SSNHL patients. The strong association between younger age and improved hearing recovery in SSNHL has important implications for clinical practice. When evaluating and managing SSNHL patients, clinicians should consider age as a key prognostic factor. Younger patients may be more likely to benefit from aggressive treatment with corticosteroids, as their greater capacity for recovery may allow them to regain more of their hearing. However, it's important to remember that age is just one piece of the puzzle. Other factors, such as the severity of initial hearing loss, the presence of vertigo, and the timeliness of treatment, also play a significant role in determining hearing outcomes. Clinicians should consider all of these factors when making treatment decisions and counseling patients about their prognosis.[11-14]

The presence of vertigo at the onset of SSNHL emerged as a significant negative predictor of hearing recovery in our study. This finding echoes previous reports that have linked vertigo to poorer outcomes in SSNHL. The association between vertigo and diminished hearing recovery may stem from the intricate anatomical and functional relationship between the auditory and vestibular systems within the inner ear. To understand the implications of vertigo in SSNHL, it's essential to appreciate the intimate connection between the auditory and vestibular systems. These two sensory systems reside within the labyrinth, a complex network of fluid-filled chambers and canals nestled deep within the temporal bone of the skull. The cochlea, the spiral-shaped organ of hearing, houses thousands of tiny hair cells that convert sound vibrations into electrical signals. These signals travel along the auditory nerve to the brain, where they are interpreted as sound. The vestibular system, responsible for balance and spatial orientation, comprises three semicircular canals and two otolith organs. The semicircular canals detect

rotational movements of the head, while the otolith organs sense linear acceleration and gravity. These two systems, though distinct in their functions, are intricately interconnected. They share the same fluid-filled environment, and their sensory hair cells rely on similar mechanisms for detecting motion and converting it into neural signals. This close proximity and shared physiology make them susceptible to simultaneous damage in conditions like SSNHL. When vertigo accompanies SSNHL, it may indicate a more extensive or severe insult to the inner ear, affecting both the auditory and vestibular apparatus. This broader involvement could translate to a more challenging recovery process, as the damage extends beyond the cochlea. Imagine the inner ear as a delicate ecosystem, with the cochlea and vestibular system representing two interconnected habitats. When a disturbance, such as a viral infection or vascular insult, disrupts this ecosystem, it can affect both habitats simultaneously. If the damage is limited to the cochlea, hearing loss may occur without vertigo. However, if the vestibular system is also affected, vertigo may accompany the hearing loss. The presence of vertigo in SSNHL may signal a more widespread inflammatory response or a more severe disruption of inner ear fluid dynamics. This broader involvement could hinder the recovery process, as the damage extends beyond the hair cells of the cochlea to the delicate structures of the vestibular system. Several mechanisms may contribute to the association between vertigo and diminished hearing recovery in SSNHL. Vertigo may indicate a more intense inflammatory response within the inner ear, affecting both the cochlea and vestibular system. This widespread inflammation could exacerbate damage to hair cells and hinder their recovery. Vertigo could signal a more significant disruption of blood flow to the inner ear, compromising the delivery of oxygen and nutrients to both the cochlea and vestibular system. This vascular insufficiency could impede the healing process and hinder hair cell regeneration. If a viral infection is the underlying cause of SSNHL, the presence of vertigo may suggest a more aggressive viral invasion, affecting both the auditory and vestibular systems. This could lead to more extensive damage and a more challenging recovery process. In cases of SSNHL caused by an inner ear membrane rupture, such as a perilymph fistula, the presence of vertigo may indicate a larger or more disruptive tear, affecting both the cochlea and vestibular system. This could complicate the healing process and hinder hearing recovery. The presence of vertigo in SSNHL should alert clinicians to the possibility of a more complex and potentially challenging recovery process. Patients presenting with vertigo may require more aggressive treatment and closer monitoring to maximize their chances of hearing restoration. Clinicians should also be aware that vertigo can significantly impact a patient's quality of life, even if their hearing loss is not severe. Vertigo can cause dizziness, nausea, and imbalance, making it difficult to perform everyday activities. Patients with vertigo may require vestibular rehabilitation therapy to help them regain their balance and reduce their symptoms.[15-17]

The early initiation of corticosteroid therapy emerged as a pivotal positive predictor of hearing recovery in our study. This finding underscores the critical importance of prompt diagnosis and treatment in SSNHL, an otologic emergency that demands swift action to maximize the chances of preserving hearing. Corticosteroids, renowned for their potent anti-inflammatory properties, are believed to exert their beneficial effects through a multifaceted approach. One of the primary mechanisms by which corticosteroids promote hearing recovery is by reducing inflammation within the inner ear. SSNHL is often associated with an inflammatory response, as the body's immune system rushes to the site of injury in the cochlea. While inflammation is a natural part of the healing process, excessive or prolonged inflammation can exacerbate damage to the delicate hair cells responsible for sound transduction. Imagine the inner ear as a delicate ecosystem, with the hair cells as its vital inhabitants. When this ecosystem is disrupted by injury or infection, the immune system sends in its troops to fight off invaders and repair damage. However, like a wildfire, this inflammatory response can sometimes rage out of control, causing more harm than good. Corticosteroids act as powerful firefighters, effectively dampening this inflammatory

firestorm. They work by binding to specific receptors within cells, modulating the expression of genes involved in the inflammatory response. This leads to a decrease in the production of inflammatory mediators, such as cytokines and chemokines, which orchestrate the immune response. By reducing inflammation, corticosteroids create a more conducive environment for healing within the inner ear. The delicate hair cells are protected from further damage, and the supporting cells can focus on repairing and regenerating damaged tissues. In addition to their anti-inflammatory actions, corticosteroids also improve blood flow to the inner ear. The cochlea, like all organs, relies on a constant supply of oxygen and nutrients delivered through the bloodstream. In SSNHL, the blood supply to the cochlea may be compromised, further jeopardizing the survival of hair cells and hindering recovery. Imagine the blood vessels supplying the inner ear as a network of intricate canals, delivering essential nutrients and oxygen to the hair cells. In SSNHL, these canals may become constricted or blocked, reducing the flow of vital resources. This can starve the hair cells, making them more vulnerable to damage and hindering their ability to recover. Corticosteroids act as skilled plumbers, restoring and maintaining adequate blood flow to the inner ear. They work by relaxing the smooth muscle cells that line the blood vessels, allowing them to dilate and increase blood flow. This ensures that the cochlea receives the vital resources it needs to repair and regenerate. Furthermore, corticosteroids possess antioxidant properties, scavenging harmful free radicals that can wreak havoc on cellular structures. Free radicals, unstable molecules generated during normal metabolic processes and exacerbated by injury or inflammation, can damage DNA, proteins, and lipids, disrupting cellular function and impeding recovery. Imagine free radicals as tiny saboteurs, wreaking havoc within the cells of the inner ear. They attack and damage vital cellular components, disrupting their function and hindering their ability to repair themselves. Corticosteroids act as vigilant guardians, neutralizing these free radicals and protecting the delicate cells of the inner ear from further damage. They work by donating electrons to free radicals, stabilizing them and preventing them from causing further harm. The early administration of corticosteroids, ideally within the first few days of SSNHL onset, is crucial to capitalize on their therapeutic potential. By swiftly mitigating inflammation, improving blood flow, and neutralizing free radicals, corticosteroids can help minimize damage to the cochlear structures and enhance the chances of hearing recovery. Imagine the inner ear as a delicate flower, susceptible to wilting and damage if not properly cared for. When SSNHL strikes, it's like a sudden storm threatening to destroy this delicate flower. Corticosteroids act as a protective shield, mitigating the storm's damaging effects and giving the flower a chance to recover. The earlier the corticosteroids are administered, the more effective they are in protecting the inner ear from damage. This is because the inflammatory response and free radical production are most intense in the early stages of SSNHL. By intervening early, corticosteroids can help to prevent irreversible damage and maximize the chances of hearing recovery. Corticosteroids can be administered through various routes, including oral and intratympanic (injection into the middle ear). Both routes have been shown to be effective in improving hearing outcomes in SSNHL. Oral corticosteroids are typically the first line of treatment, as they are easy to administer and well-tolerated by most patients. They reach the inner ear through the bloodstream, providing systemic anti-inflammatory and antioxidant effects. Intratympanic corticosteroids are injected directly into the middle ear, allowing for a higher concentration of the drug to reach the inner ear. This route may be particularly beneficial for patients with severe hearing loss or those who have not responded to oral corticosteroids.[18-20]

5. Conclusion

In conclusion, this study identified key prognostic factors for hearing recovery in SSNHL patients in Singapore. Younger age, absence of vertigo at onset, and prompt initiation of corticosteroid therapy were independently associated with better hearing outcomes. These findings underscore the importance of early diagnosis and treatment to maximize the chances of hearing recovery. While the degree of initial

hearing loss and presence of tinnitus did not significantly influence recovery in this cohort, further investigation with larger sample sizes and longer follow-up durations is warranted to confirm these observations. This study contributes valuable insights to guide clinical decision-making and improve patient counseling for this debilitating condition.

6. References

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