

Preoperative Temporal Bone Imaging Predicts Surgical Complexity in Pediatric Cochlear Implantation: Indonesian Study

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ABSTRACT

Cochlear implantation is widely accepted for children with bilateral profound sensorineural hearing loss, though anatomical variations of the temporal bone may increase surgical difficulty. To evaluate preoperative CT and MRI findings in Indonesian pediatric cochlear implant candidates and assess surgical difficulty using the Potential Difficult Surgery (PDS) scoring system. A retrospective descriptive study was conducted on 49 children (98 ears) with congenital bilateral sensorineural hearing loss who underwent CT and MRI between 2012 and 2017. Anatomical characteristics were assessed using Vaid's system, which scores four parameters: mastoid pneumatization, facial recess width, canal-sigmoid sinus alignment, and cochlear basal turn orientation. No inferential statistical analysis or hypothesis testing was performed in this study. Most ears demonstrated favorable anatomy: well-pneumatized mastoids (79.59%), wide facial recesses (83.67%), favorable sigmoid alignment (79.36%), and optimal basal turn orientation (89.79%). However, 20.41% had poor pneumatization and misaligned sigmoid sinuses, 16.32% had narrow facial recesses, and 6.12% showed inner ear malformations. PDS classification revealed Grade 1 (minimal complexity) in 41.84%, Grade 2 (moderate complexity) in 53.06%, and Grade 3 (high complexity) in 5.10% of ears, with most patients facing moderate surgical complexity. This study provides the first local application of the PDS score to Indonesian pediatric cases, demonstrating that CT and MRI with PDS scoring effectively anticipate intraoperative challenges and guide surgical planning.

Keywords: Cochlear Implant, CT-Scan, MRI, Pediatric Otolaryngology, Surgical Difficulty, PDS Score

RESUMO

O implante coclear é amplamente aceito para crianças com perda auditiva neurossensorial profunda bilateral, embora variações anatômicas do osso temporal possam aumentar a dificuldade cirúrgica. Avaliar os achados pré-operatórios de TC e RM em candidatos pediátricos indonésios a implante coclear e avaliar a dificuldade cirúrgica usando o sistema de pontuação Potential Difficult Surgery (PDS). Um estudo descritivo retrospectivo foi conduzido em 49 crianças (98 orelhas) com perda auditiva neurossensorial bilateral congênita que foram submetidas a TC e RM entre 2012 e 2017. As características anatômicas foram avaliadas usando o sistema de Vaid, que pontua quatro parâmetros: pneumatização mastoide, largura do recesso facial, alinhamento canal-seio sigmoide e orientação da espira basal coclear. Nenhuma análise estatística inferencial ou teste de hipóteses foi realizado neste estudo. A maioria das orelhas demonstrou anatomia favorável: mastoides bem pneumatizadas (79,59%), recessos faciais amplos (83,67%), alinhamento sigmoide favorável (79,36%) e orientação ótima da espira basal (89,79%). No entanto, 20,41% apresentaram pneumatização deficiente e seios sigmóides desalinhados, 16,32% tinham recessos faciais estreitos e 6,12% mostraram malformações do ouvido interno. A classificação PDS revelou Grau 1 (complexidade mínima) em 41,84%, Grau 2 (complexidade moderada) em 53,06% e Grau 3 (alta complexidade) em 5,10% das orelhas, com a maioria dos pacientes enfrentando complexidade cirúrgica moderada. Este estudo fornece a primeira aplicação local da pontuação PDS a casos pediátricos indonésios, demonstrando que TC e RM com pontuação PDS antecipam efetivamente desafios intraoperatórios e orientam o planejamento cirúrgico.

Palavras-Chave: Implante Coclear, Tomografia Computadorizada, Ressonância Magnética, Otolaryngologia Pediátrica, Dificuldade Cirúrgica, Pontuação PDS

INTRODUCTION

Cochlear implants are medical devices that serve to stimulate the auditory nerve in individuals with severe-to-profound sensorineural hearing loss (SNHL) by converting sound waves into electrical signals. This device is considered the most effective solution for children with bilateral profound SNHL who receive limited benefit from hearing aids [1, 2]. According to the World Health Organization (WHO), approximately 34 million children globally experience disabling hearing loss, which can significantly impact speech and language development, academic performance, and social interaction [3]. Cochlear implantation in children presents a variety of anatomical challenges due to the narrower and smaller structures of the pediatric temporal bone, increasing the risk of complications such as facial

nerve injury and suboptimal electrode placement [4]. The primary objective of preoperative imaging using both CT and MRI is to assess the condition of cochlear and temporal bone structures, aiding in the prediction of surgical difficulty and minimizing intraoperative risks [5]. Several anatomical variations are known to affect the complexity of cochlear implantation, including mastoid pneumatization, facial recess width, canal-sigmoid sinus alignment, and cochlear basal turn orientation [6]. These radiological features can be quantified using the Potential Difficult Surgery (PDS) scoring system, which has been proposed as a tool to predict surgical difficulty and estimate operative duration. While this system has been evaluated internationally, it has yet to be validated in Indonesia. Globally, extensive research has

established the correlation between preoperative imaging findings and surgical outcomes in cochlear implantation, with studies from Europe, North America, and other Asian countries demonstrating the predictive value of anatomical scoring systems. International literature consistently shows that specific temporal bone characteristics can reliably predict operative complexity, duration, and complication rates. However, significant knowledge gaps exist regarding the applicability of these findings to Indonesian pediatric populations. The anatomical variations and morphometric characteristics of temporal bone structures may differ across ethnic populations, potentially affecting the validity of internationally-derived scoring systems [7]. Furthermore, no data currently exists on the distribution of anatomical risk factors or the performance of predictive scoring systems in Indonesian children undergoing cochlear implantation. This gap limits evidence-based surgical planning and risk stratification in the local clinical setting. To date, no studies in Indonesia have systematically applied the PDS scoring method to analyze anatomical structures in pediatric cochlear implant candidates.

As a result, the clinical utility of radiological predictors in Indonesian populations remains unclear. This study represents the first effort to utilize the PDS system in an Indonesian pediatric context, aiming to evaluate CT and MRI findings in patients from West Java and classify predicted surgical complexity. The novelty of this research lies in providing localized anatomical data that has previously been unavailable, thereby bridging the gap between global literature and the unique anatomical profiles of Indonesian children with SNHL. The findings are expected to provide foundational data for surgical planning and offer new insights into pediatric cochlear implantation in Indonesia.

MATERIAL

Study Design and Settings

This study used a retrospective descriptive design and was conducted in the Department of Otorhinolaryngology – Head and Neck Surgery at Hasan Sadikin General Hospital, Bandung, Indonesia. The study analyzed medical records and radiological data from pediatric patients evaluated for cochlear implantation between January 2012 and December 2017. This study employed a purely descriptive analytical approach to provide foundational data on anatomical variations in the Indonesian pediatric population [8]. Given the absence of prior local studies on PDS scoring applications, the primary objective was to establish baseline prevalence data and anatomical characteristics rather than to test statistical associations [9].

The descriptive methodology was specifically chosen to create a comprehensive database of anatomical findings that can serve as a reference for future correlational and outcome-based studies in this population [10]. While correlational analysis between PDS scores and surgical outcomes would strengthen the predictive validity of these findings, such analysis was beyond the scope of this initial descriptive study and represents an important direction for future prospective research.

Imaging Procedures

High-resolution computed tomography (HRCT) scans were performed using a 64-slice Siemens SOMATOM Definition AS CT scanner with 0.6 mm slice thickness, 120 kVp, and automatic mA modulation. Magnetic resonance imaging (MRI) was conducted using a 3.0 Tesla Philips Achieva scanner with T2-weighted 3D CISS and axial T1-weighted post-contrast sequences. Imaging included the temporal bone, internal auditory canal, cochlea, and vestibulocochlear nerve.

Image Analysis

Imaging data were evaluated independently by two otologic specialists using established criteria. The assessment focused on: Degree of mastoid pneumatization; Facial recess width; Relative alignment between the external auditory canal and sigmoid sinus; Orientation of the basal turn of the cochlea; Additional Anomalies: cochlear hypoplasia/aplasia, vestibular deformities, vestibulocochlear nerve abnormalities. The anatomical classifications were based on references by Vaid et al.[11] and Sennaroglu. Discrepancies in interpretation were resolved through discussion and consensus between the two reviewers.

Classification of Surgical Complexity (PDS Score)

To describe the potential difficulty of cochlear implantation, the study used the Potential Difficult Surgery (PDS) score system adapted from Vaid et al.[11] The score consists of four key anatomical parameters graded on a scale from 0 to 3. The total score is then categorized into: Grade 1 (0–3): minimal surgical difficulty; Grade 2 (4–7): moderate surgical difficulty; Grade 3 (≥8): high surgical difficulty. PDS grading was used descriptively to summarize the proportion of patients in each complexity category, without direct comparison to surgical duration or outcomes.

Data Collection and Analysis

Demographic variables (age, sex, parental occupation, and education) and anatomical findings from imaging were extracted from medical records. All data were summarized descriptively using frequency and percentage distributions. No inferential statistics or hypothesis testing were performed, as this study was not designed to establish associations or causality.

Ethics, Consent, and Permissions

The study received approval from the ethics board at the Faculty of Medicine, Universitas Padjadjaran. Consent for participation in the research study was obtained as part of the overall consent process for cochlear implant surgery.

Patients

The study included 49 pediatric patients (25 males and 24 females) aged between 9 months and 15 years, all diagnosed with bilateral congenital profound sensorineural hearing loss. Inclusion criteria were: (1) availability of complete preoperative CT and MRI scans; and (2) evaluation for cochlear implantation within the study period. Patients with incomplete imaging, previous temporal bone surgery, or syndromic congenital anomalies were excluded.

Table 1(a): Subject Characteristic

Characteristics	N (%)
Gender	
Boy	25 (51,02%)
Girl	24 (48,98%)
Age of Diagnosis	

Table 1(b): Subject Characteristic

Characteristics	N (%)
Gender	
Boy	25 (51,02%)
Girl	24 (48,98%)
Age of Diagnosis	
< 1y	27 (55,10%)
1y-3y	20 (40,81%)
>3y - 5y	2 (04,09%)
>5y	0
Age of Implantation	
< 1y	1 (2,04%)
1y - 3y	18 (36,73%)
>3y - 5y	23 (46,93%)
>5y	7 (14,28%)

Table 2: Parents Characteristic

Characteristics	N(%)
Father's Job	
Government Employee	16 (32,66%)
Private Employee	33 (67,34%)
Level of Education	
High School	9 (18,37%)
College	40 (81,63%)
Mother	
House Wife	36 (73,47%)
Working	13 (26,53%)
Level of Education	
High School	15 (30,62%)
College	34 (69,38%)
Family Income Level	
Rp 2,6m-6m/Month	21 (42,85%)
>Rp 6m/Month	28 (57,15%)

Result

A total of 49 pediatric patients were included in this study, comprising 25 males (51.02%) and 24 females (48.98%), with an age range from 9 months to 15 years. The majority of subjects (27 patients, 55.10%) were under 1 year of age at the time of initial evaluation.

Sociodemographic data indicated that most fathers were private employees (67.34%), and 81.63% had attained a college-level

education. Meanwhile, 73.47% of mothers were housewives, with 69.38% also having college-level education. Over half of the families (57.15%) reported a monthly household income above IDR 6 million, indicating a middle-to-upper socioeconomic background.

Radiological Findings

From a total of 98 ears (49 patients), detailed analysis of CT and MRI imaging revealed the following anatomical features relevant to cochlear implantation.

Table 3 (a): Anatomical Finding of CT and MRI

Imaging Finding	N (%)
a. Degree of Mastoid Pneumatization	
Well Pneumatized	39 (79,59%)
Hypo/Non-Pneumatized	10 (20,41%)
b. Facial Recess Anatomy	
Narrow (<3mm)	8 (16,32%)
Wide (>3mm)	41 (83,68%)
c. Descending Segment of Facial Nerve Canal	
Normal	49 (100%)
Overhanging the Round Window	0
d. Position of the Jugular Bulb	
Normal	49 (100%)
High Riding/Dehiscent	0
e. Posterior Wall of External Auditory Canal/Sinus Sigmoid Lines	
Favorable	39 (79,59%)
Unfavorable	10 (20,41%)
f. Posterior Wall of External Auditory Canal/Long Axis of Basal Turn Line	
Favorable	44 (89,79%)
Not favorable	5 (10,21%)
g. Relative Position of the Basal Turn of Cochlea to the Maleoincudal Joint in Axial Plane	
Favorable	49 (100%)
Not Favorable	0
h. Lines Along the Anterior Margins of the IACs	
Parallel Line	49 (100%)
Angulated or Intersecting	0

Table 3 (b): Anatomical Finding of CT and MRI

Imaging Finding	N (%)
i. Associated Congenital Anomalies of Temporal Bone	
Normal	49 (100%)
Abnormal	0
j. Cochlea	
Normal	49 (100%)
Hypoplasia/Absent	0
k. Vestibulocochlear Nerve	
Normal	49 (100%)
Hypoplasia/Absent	0

Mastoid Pneumatization

It is found that well-pneumatized mastoid was observed in 78 ears (79.59%) and Hypopneumatization was detected in 20 ears (20.41%) where this is a condition whether potentially associated with prolonged drilling time and increased surgical difficulty.

Facial Recess Width

A wide facial recess (>3 mm) was identified in 82 ears (83.67%) and a narrow facial recess (<3 mm) identified in 16 ears (16.32%) which may present technical challenges during posterior tympanotomy and increase risk to the facial nerve (Figure 1).

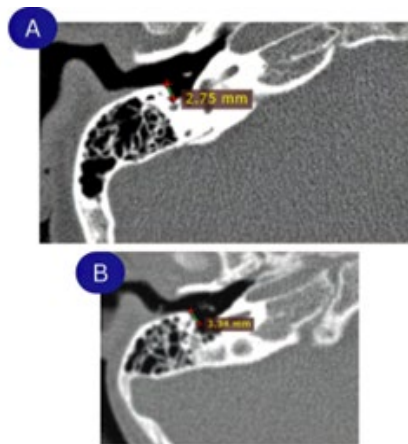


FIGURE 1: A. Narrow Facial Recess, B. Wide Facial Recess

Canal-Sigmoid Sinus Alignment

Favorable alignment was found in 78 ears (79.36%), where the posterior wall of the external auditory canal and the sigmoid sinus ran

parallel. Unfavorable (misaligned) cases were observed in 20 ears (20.41%), which may limit the surgical field and elevate the risk of intraoperative bleeding (Figure 2).

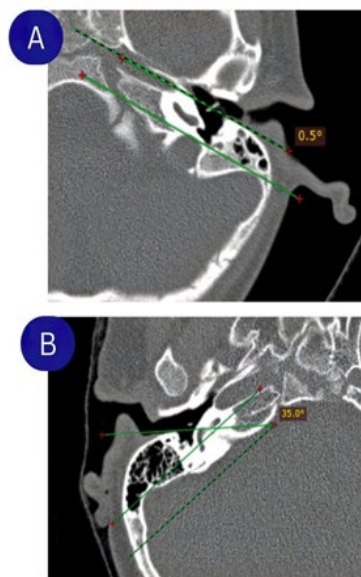


FIGURE 2: A Favourable Alignment, B. Unfavourable Alignment

Basal Turn Axis of the Cochlea

Normal alignment of the posterior wall and basal turn was seen in 88 ears (89.79%).

Deviated or intersecting alignment occurred in 10 ears (10.21%), potentially complicating the round window approach for electrode insertion (Figure 3).

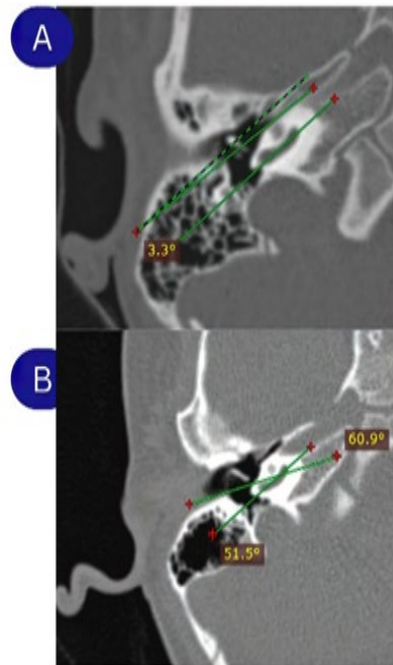


FIGURE 3: A. Favourable Alignment, B. Intersecting Alignment

Inner Ear Malformations

Inner ear anomalies were found in 6 ears including: 1) Incomplete Partition Type II in 2 ears; (2) Common cavity malformation 1 ear; (3) Cochlear aplasia 1 ear);

(4) Cochleovestibular nerve hypoplasia was found in 2 ears (Figure 4).

Other Observations

Deviated or intersecting alignment occurred in 10 ears (10.21%), potentially complicating the round window approach for electrode insertion. The anterior margins of the internal auditory canals (IACs) were parallel in all subjects (100%), suggesting normal cochlear orientation.

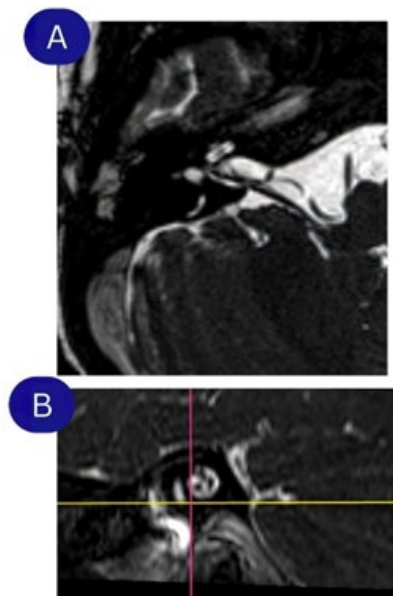


FIGURE 4: Normal Vestibulocochlear Nerve and Facial Nerve in Axial (A) and Sagittal MRI View (B)

PDS Score Classification

Using the Potential Difficult Surgery (PDS) scoring system, the anatomical features of each ear were graded to estimate the anticipated difficulty of cochlear implantation surgery. Based on the combined anatomical parameters:

Grade 1 (PDS 0–3): 41 ears (41.84%) – minimal surgical complexity.

Grade 2 (PDS 4–7): 52 ears (53.06%) – moderate surgical complexity.

Grade 3 (PDS ≥8): 5 ears (5.10%) – high surgical complexity.

The majority of patients (Grade 2) demonstrated moderate anatomical challenges, particularly in cases with narrow facial recesses and canal-sigmoid misalignment. While the PDS score does

not predict exact operative duration in this study, the gradation provides a standardized reference for preoperative planning and risk anticipation.

Discussion

This study aimed to evaluate preoperative CT and MRI findings in pediatric cochlear implant candidates with congenital sensorineural hearing loss in West Java, Indonesia, and to classify the anatomical variations that may influence surgical complexity. The results confirm that several structural anomalies relevant to cochlear implantation are present in this population, and the majority fall within the moderate risk category as classified by the Potential Difficult Surgery (PDS) score. A well-pneumatized mastoid was found in nearly 80% of the evaluated ears. This is consistent with findings by [11], who noted that good pneumatization facilitates easier drilling during mastoidectomy and reduces operative time. Conversely, hypo pneumatization, present in 20.41% of ears, may complicate access and increase drilling time, particularly in younger patients whose mastoid air cells are not fully developed. This finding aligns with previous studies by [12], which highlighted the importance of preoperative recognition of mastoid status for surgical planning. Facial recess narrowing was identified in 16.32% of ears, which may pose challenges during the posterior tympanotomy approach. Although this percentage is lower than that reported in other populations found narrow recesses in 30.90% of patients our findings support the notion that a narrow facial recess (<3 mm) is a significant anatomical risk factor for facial nerve injury or electrode insertion difficulty. This anatomical constraint has been cited in both cadaveric and intraoperative studies [13], especially when surgical access through the round window is required. The canal-sigmoid sinus relationship also plays a critical role in defining the surgical field. In this study, 20.41% of ears had unfavorable alignment, consistent with prior reports that suggest such misalignment increases the risk of excessive bleeding and limits posterior exposure [14]. Notably, the presence of unfavorable sigmoid sinus positioning may also dictate the need for a modified surgical approach or greater operative caution. In terms of cochlear orientation, most patients demonstrated favorable alignment between the posterior wall and the basal turn of the cochlea. However, in 10.21% of cases, the misalignment could potentially obscure the round window and hinder smooth electrode insertion. Studies by Sennaroglu and Tahir and Vaid et al. [11] similarly emphasize that an unfavorable basal turn angle contributes to intraoperative technical difficulty, especially in cases with cochlear malformations. Only a small proportion of patients (4.08%) presented with gross inner ear malformations, such as incomplete partition type II or cochlear aplasia. These malformations are well-documented to increase the risk of complications like cerebrospinal fluid leakage, incomplete insertion, or device migration [15]. Interestingly, the vestibulocochlear nerve appeared structurally intact in most cases, differing from studies in other Asian populations that report higher incidences of cochlear nerve deficiency (CND), which may require alternative treatment such as auditory brainstem implantation. Using the PDS score, this study categorized most patients (53.06%) as Grade 2, indicating moderate surgical complexity [16]. This reinforces the utility of PDS as a simple yet effective framework for risk stratification prior to cochlear implantation [11]. Although this study does not correlate the scores with actual operative duration due to its descriptive design, the PDS classification remains a

useful predictive tool. Its adoption could help guide surgical expectations and optimize intraoperative resource planning, particularly in centers where cochlear implant programs are expanding. While this study successfully applied the PDS scoring system to classify anatomical complexity in Indonesian pediatric patients, it is important to acknowledge that the clinical utility of these scores requires validation against actual surgical outcomes [8]. Ideally, PDS scores should be correlated with measurable intraoperative parameters such as operative duration, estimated blood loss, facial nerve monitoring changes, and complication rates including facial nerve injury, cerebrospinal fluid leaks, or electrode insertion difficulties [17]. The absence of such outcome correlation in this study represents a significant limitation that prevents definitive validation of the PDS system's predictive accuracy in this population [18]. Future prospective studies incorporating detailed surgical documentation, intraoperative timing, and complication tracking are essential to establish the clinical validity and reliability of PDS scoring as a preoperative risk stratification tool in Indonesian cochlear implant programs. Such validation studies would provide surgeons with evidence-based metrics to guide patient counseling, resource allocation, and surgical planning decisions. It is important to emphasize that the findings from this West Java cohort are broadly consistent with international literature but also provide region-specific insight [19, 20]. Environmental, genetic, and healthcare access differences may explain the slightly lower prevalence of complex anatomical anomalies compared to global reports. This underlines the need for localized imaging databases to support precision in pediatric otologic surgery across diverse populations.

Conclusion

This study demonstrates that several anatomical variations identifiable through preoperative CT and MRI imaging particularly mastoid hypopneumatization, narrow facial recess, canal-sigmoid misalignment, and basal turn deviation are present in a significant proportion of pediatric cochlear implant candidates in West Java. The application of the Potential Difficult Surgery (PDS) score enabled structured classification of surgical complexity, with most patients falling into the moderate-risk category. These findings underscore the essential role of imaging in surgical planning and candidate selection for cochlear implantation. This study has several important limitations that must be acknowledged. First, the retrospective descriptive design inherently limits the ability to establish causal relationships between anatomical features and surgical outcomes, and may introduce selection bias in patient inclusion. Second, all radiological assessments were performed by two otologic specialists without formal standardized inter-rater reliability testing or kappa coefficient calculations, which could affect the consistency and reproducibility of PDS scoring measurements across different evaluators. This limitation is particularly relevant given that subtle anatomical variations require precise measurement and subjective interpretation. Third, this study was conducted exclusively at a single tertiary center in West Java, which significantly limits the generalizability of findings to other regions within Indonesia or broader Southeast Asian populations. Anatomical variations may differ substantially across different ethnic subgroups, geographic regions, and healthcare settings, potentially affecting the universal applicability of these results. Fourth, the study's purely descriptive

nature prevents the establishment of direct statistical correlations between PDS scores and actual surgical outcomes, such as operative duration, intraoperative complications, bleeding volume, or facial nerve monitoring changes. Fifth, the relatively small sample size of 49 patients (98 ears) may not adequately capture the full spectrum of anatomical variations present in the broader Indonesian pediatric population with congenital hearing loss.

Additionally, this study did not include long-term follow-up data to assess the clinical relevance of the anatomical findings in relation to device performance, auditory outcomes, or quality of life measures. The absence of correlation with actual surgical complexity, operative time, and complication rates limits the clinical validation of the PDS scoring system in this population. Finally, advanced imaging techniques such as volumetric analysis, 3D reconstruction, or cochlear morphometry were not utilized, which may have enhanced spatial accuracy and provided more precise anatomical measurements. The lack of comparison with other anatomical scoring systems or

validation against international cohorts also limits the broader clinical applicability of these findings. This study is limited by its retrospective and descriptive design, which prevents the establishment of causal relationships or statistical associations.

Operative duration and complication data were not available, and therefore the predictive value of anatomical findings could not be confirmed empirically. Furthermore, advanced imaging techniques such as volumetric analysis or 3D reconstruction were not utilized, which may have enhanced spatial accuracy and preoperative simulation. Despite these limitations, the findings highlight the critical role of imaging in pediatric cochlear implantation. The application of a structured classification system like the PDS score enables early identification of potentially challenging cases. Future prospective studies are recommended to validate the correlation between PDS grading and actual surgical outcomes and to explore the integration of imaging findings with audiological and developmental follow-up data.

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