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Digital Radiographic Evaluation of Skull Dimensional Patterns in Paediatric Patients with Adenoids: Emphasis on Anterior-Posterior versus Transverse Diameter

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Abstract: ***Background:*** Adenoid hypertrophy is a clinical condition of significant concern in children, with implications for craniofacial growth and respiratory health. The relationship between skull dimension patterns and adenoid pathology has not been clearly defined, particularly as it relates to the relative significance of anterior-posterior vs. transverse diameters in predicting disease outcomes. ***Methods:*** This is a cross-sectional study enrolling 80 children aged 3-12 years who had symptoms indicative of adenoid hypertrophy. Lateral cephalometric X-rays were taken using standard digital radiography protocols. Digital measurements were taken of the anterior-posterior and transverse diameters of the skull using calibrated software instruments. Adenoid severity was graded as mild, moderate, or severe based on radiographic evaluation. Statistical analysis was done using SPSS v.26including multinomial logistic regression and Cox proportional hazards modeling to examine associations between skull measurements and adenoid severity. ***Results:*** Anterior-posterior diameter was 118.4 ± 8.5 mm, while the transverse diameter was 126.2 ± 9.1 mm (p=0.032). Transverse dominance was observed in 71.3% of patients, and prevalence was significantly increased in advanced age groups (80% in 9-12 years vs 68% in 3-5 years, p=0.045). Multinomial logistic regression revealed anterior-posterior diameter to significantly predict moderate (RRR=1.15, p=0.005) and severe adenoid hypertrophy (RRR=1.22, p=0.001). The Cox proportional hazards model indicated that with each 1 mm increase in anterior-posterior diameter, the risk of advancing to severe adenoid obstruction was 12% increased (HR=1.12, p=0.006). ***Conclusion:*** This study indicates the anterior-posterior diameter of the skull as a predictor of the severity and course of adenoid hypertrophy in children, despite transverse patterns of growth being dominant.

Keywords: Digital Radiography, Skull Dimensional Pattern, Paediatric, Adenoids.

Original Researcher Article

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Article at a glance:

Study Purpose: *To examine the association between skull dimensions and adenoid hypertrophy severity in children, focusing on the anterior-posterior and transverse diameters.*

Key findings: *The anterior-posterior diameter significantly predicts moderate and severe adenoid hypertrophy, while transverse growth patterns dominate in most children.*

Newer findings: *The anterior-posterior skull diameter predicts the severity of adenoid hypertrophy and its progression, despite transverse growth being dominant.*

Abbreviations: *CT - Computed Tomography, RRR - Relative Risk Ratio, HR - Hazard Ratio.*

INTRODUCTION

Hypertrophy of the adenoids is among the most prevalent upper airway illnesses in children, affecting approximately 10-15% of children all over the world and being one of the principal reasons for sleep-disordered breathing and chronic nasal obstruction.[1] The adenoids, lymphoid tissue in the nasopharynx, play a role in immune function during early life but may become pathologically enlarged due to recurrent infection, allergic responses, or constitutional factors.[2] The clinical significance of adenoid hypertrophy is not nasal obstruction alone but a constellation of complications including obstructive sleep apnea, chronic rhinosinusitis, and potential impacts on craniofacial development.[3] The relationship between adenoid pathology and craniofacial morphology has been the subject of increasing interest during the last few decades, with emerging evidence indicating that patterns of skull dimensions can influence both the susceptibility to adenoid hypertrophy and the clinical manifestation of the disease.[4] Traditional cephalometric investigations have focused primarily on sagittal relationships and airway dimensions, with relatively less attention being directed to the relative significance of anterior-posterior vs. transverse skull dimensions as predictors of adenoid disease.[5] Understanding these dimensional correlations is relevant to clinicians who diagnose and treat pediatric lung disease because it can inform patterns of disease and direct treatment decisions.[6] Digital radiography has revolutionized the assessment of craniofacial structures with improved measurement precision and reduced radiation doses compared to conventional radiographic techniques.[7] Advanced imaging software has enabled complex morphometric study previously unfeasible or unreliable using manual measuring techniques.[8] These technological developments have enabled more comprehensive investigations into the complex interrelations between skull measurements and adenoid disease, as well as the possibility of sophisticated diagnostic and prognostic applications.[9] A previousstudy by Kim *et al.* has demonstrated correlations between adenoid size and some cephalometric parameters, the majority of which have been with nasopharyngeal airway size and sagittal skeletal relationships.[10] The comparative significance of anterior-posterior as opposed to transverse cranial dimensions in predicting adenoid hypertrophy severity and development, however, remains poorly defined.[11] This information gap is particularly pertinent in light of the possible clinical implications for the early identification of patients at risk for severe adenoid obstruction and the development of adenoid obstruction-targeted management schemes .[12] This study aims to bridge this gap with an in-depth digital radiographic evaluation of skull dimensional patterns among children presenting with adenoid hypertrophy, with a specific interest in the relative predictive value of anterior-posterior versus transverse diameters. Through the application of advanced statistical modeling techniques including multinomial logistic regression and Cox proportional hazards modeling, the present study endeavors to ascertain the relative importance of these dimensional measures in forecasting adenoid severity and ultimate development of severe obstruction.

METHODS

This cross-sectional study was conducted at Jalalabad Ragib-Rabeya Medical College, Sylhet, Bangladesh from January, 2020 to December, 2023. A total of 80 pediatric patients presenting with symptoms suggestive of adenoid hypertrophy were enrolled. Lateral cephalometric radiographs were obtained for all participants using standardized digital radiography techniques. The AP and transverse diameters of the skull were measured digitally using calibrated software tools. Adenoid size was categorized into mild, moderate, and severe based on radiographic evaluation. Demographic data including age and gender were recorded. The primary outcome was the time to progression to severe adenoid obstruction, which was followed retrospectively or prospectively depending on patient records. Statistical analysis included descriptive statistics to summarize baseline characteristics. Multinomial logistic regression was initially used to assess the association between skull diameters, age, gender, and adenoid size categories. Subsequently, Cox proportional hazards regression was performed to evaluate the effect of AP and transverse diameters, age, and gender on the hazard of progressing to severe adenoid obstruction Statistical significance was set at $p < 0.05$, and all analyses were conducted using [specify software, e.g., SPSS version 26.

RESULTS

Table 1: Basic Characteristics of the Study Population (n=80)

Variable	Frequency (n)	Percentage (%)
Age Group (years)		
3-5	25	31.3%
6-8	30	37.5%
9-12	25	31.3%
Gender		
Male	42	52.5%
Female	38	47.5%
Adenoid Size		
Mild	20	25%
Moderate	35	43.8%
Severe	25	31.3%

Table 1 represents the demographic distribution of the study group, and it is quite evenly divided by age group and gender. The age distribution is relatively evenly distributed in the youngest age group (3-5 years, 31.3%) and the oldest age group (9-12 years, 31.3%), but with greater representation in the middle group (6-8 years, 37.5%). Gender distribution reveals a mild male predominance (52.5% vs 47.5%), which is also in line with epidemiological patterns of adenoid hypertrophy. Adenoid size distribution reveals that the most frequent category was moderate hypertrophy (43.8%), followed by severe (31.3%) and mild (25.0%) categorization. This distribution pattern suggests that the majority of the patients had clinically significant adenoid enlargement that required treatment or careful follow-up.

Table 2: Distribution of Anterior-Posterior Skull Diameters

Measurement Range (mm)	Frequency (n)	Percentage (%)	p-value
< 110	15	18.8	
110–120	30	37.5	
> 120	35	43.8	0.041*

Table 2 shows the distribution of anterior-posterior skull diameters. The anterior-posterior skull diameter measurement was found to have high clustering in the higher ends, with 43.8% of the patients having diameters above 120 mm, while 37.5% had diameters within 110-120 mm. Only 18.8% of the patients were measured below 110 mm, and that implies the majority of the study group had relatively higher anterior-posterior measurements. The statistical significance (p=0.041) indicates that such a pattern of distribution is different enough from normal expected distributions to indicate the existence of some relationship between adenoid pathology and skull morphology.

Table 3: Distribution of Transverse Skull Diameters

Measurement Range (mm)	Frequency (n)	Percentage (%)	p-value
< 120	20	25%	
120–130	35	43.8%	
> 130	25	31.3%	0.058

Table 3 denotes that the measurements of the transverse diameters have a more balanced distribution between the measurement ranges, with the maximum percentage (43.8%) being the middle range of 120-130 mm. The distribution shows 31.3% of patients having measurements above 130 mm and 25.0% below 120 mm. Although the p-value is approaching statistical significance (p=0.058), it is still below the threshold, and therefore transverse diameter distribution may be less significantly associated with adenoid pathology compared to anterior-posterior measurements.

Table 4: Comparison of Anterior-Posterior vs. Transverse Diameters

Dimension	Mean ± SD (mm)	Range	p-value
Anterior-Posterior	118.4 ± 8.5	105–130	
Transverse	126.2 ± 9.1	110–140	0.032*

Table 4 comparison indicates that transverse diameters are always larger than anterior-posterior measurements by mean differences of 126.2 ± 9.1 mm and 118.4 ± 8.5 mm respectively. Statistical significance (p=0.032) adds force to the observation that this difference in measurement is not accidental but significant. The increased range of variation observed in transverse measurements (110-140 mm) compared to anterior-posterior measurements (105-130 mm) is an indication of greater variability in lateral skull growth.

Table 5: Skull Dimensional Patterns by Age Group

Age Group (years)	AP Dominant (n, %)	Transverse Dominant (n, %)	p-value
3-5	8 (32.0%)	17 (68%)	
6-8	10 (33.3%)	20 (66.7%)	
9-12	5 (20.0%)	20 (80%)	0.045*

Table 5 denotes skull dimensional patterns by age group. Analysis by age group stratified demonstrates a step-wise progression in transverse dominance with advancing age, from 68% in the youngest group to 80% in the oldest group. This trend is of statistical significance (p=0.045), and it means that dimensional patterns of the skull change in a predictable fashion in child development.

Table 6: Skull Dimensional Patterns by Gender

Gender	AP Dominant (n, %)	Transverse Dominant (n, %)	p-value
Male	18 (42.9%)	24 (57.1%)	
Female	10 (26.3%)	28 (73.7%)	0.067

Table 6 demonstrates the skull dimensional patterns by gender. Female analysis demonstrates considerable differences in patterns of dimensional dominance wherein females show a higher proportion of transverse dominance (73.7%) compared to males (57.1%). Although the discrepancy is on the verge of statistical significance (p=0.067), it suggests potential sexual dimorphism in craniofacial developmental patterns. The greater prevalence of anterior-posterior dominance in males (42.9% vs 26.3%) may be because of sex differences in growth patterns in boys and girls during childhood.

Table 7: Correlation of Skull Dimensions with Adenoid Size

Adenoid Size	Mean AP Diameter (mm)	Mean Transverse Diameter (mm)	p-value
Mild	112.2 ± 6.7	121.4 ± 7.2	
Moderate	117.8 ± 7.5	127.1 ± 8.6	
Severe	123.1 ± 8.9	130.2 ± 9.5	0.022*

*p < 0.05 is considered statistically significant.

Table 7 underlies the correlation of skull dimensions with adenoid size. This division shows progressive increases in anterior-posterior and transverse diameters by adenoid severity category. The anterior-posterior diameter shows marked progression from mild (112.2 ± 6.7 mm) to severe (123.1 ± 8.9 mm) adenoid hypertrophy, while transverse measurements increase from 121.4 ± 7.2 mm to 130.2 ± 9.5 mm. The statistical difference (p=0.022) confirms that skull size is meaningfully correlated with adenoid severity. The greater relative increase in anterior-posterior size (10.9 mm difference) over transverse changes (8.8 mm difference) indicates that sagittal skull growth is more probably associated with adenoid disease than lateral expansion, supporting the hypothesis that specific patterns of dimension cause or result in adenoid hypertrophy.

Table 8(A): Multinomial Logistic Regression Analysis of Factors Associated with Adenoid Size Categories

Predictor Variable	Relative Risk Ratio (RRR)	95% Confidence Interval	p-value
Severe vs. Mild Adenoid Size			
Anterior-Posterior Diameter (per mm)	1.22	1.10–1.36	0.001*
Transverse Diameter (per mm)	1.05	0.98–1.12	0.142
Age (per year)	0.89	0.78–1.03	0.110
Gender (Female vs. Male)	1.51	0.89–2.56	0.124
Moderate vs. Mild Adenoid Size			
Anterior-Posterior Diameter (per mm)	1.15	1.04–1.26	0.005*
Transverse Diameter (per mm)	1.03	0.97–1.09	0.198
Age (per year)	0.93	0.82–1.05	0.230
Gender (Female vs. Male)	1.34	0.79–2.28	0.284

Table 8(B): Cox Proportional Hazards Model for Factors Associated with Time to Severe Adenoid Obstruction

Predictor Variable	Hazard Ratio (HR)	95% Confidence Interval	p-value
Anterior-Posterior Diameter (per mm)	1.12	1.03–1.21	0.006*
Transverse Diameter (per mm)	1.07	0.99–1.16	0.075
Age (per year)	0.95	0.84–1.08	0.420
Gender (Female vs. Male)	1.32	0.77–2.26	0.310

Table 8(C):Key Findings from the Cox Model

Predictor Variable	Hazard Ratio (HR)	95% Confidence Interval	p-value
Anterior-Posterior Diameter (per mm)	1.12	1.03–1.21	0.006
Transverse Diameter (per mm)	1.07	0.99–1.16	0.075

The multinomial logistic regression equation from Table 8(A) identifies the anterior-posterior diameter as the most significant predictor of adenoid severity, with relative risk ratios of 1.15 (p=0.005) for moderate and 1.22 (p=0.001) for severe adenoid hypertrophy compared to mild disease. For each increment in anterior-posterior diameter by one millimeter, the risk of severe adenoid hypertrophy increases by 22%, and moderate hypertrophy increases by 15%. Transverse diameter, age, and gender fail to achieve statistical significance, illustrating the strongest predictor of adenoid severity as the anterior-posterior dimension. Survival analysis and findings from Table 8(B) and 8(C) reveal anterior-posterior diameter to have a significant influence on the risk of progressing to severe adenoid obstruction (HR=1.12, p=0.006), with each increment in millimeter count relating to an increase in risk of progression by 12%. This validates anterior-posterior diameter as a prognostic indicator for disease progression and enables clinicians to stage the patients at higher risk of developing severe obstruction. The absence of strong correlation between transverse diameter, gender, and age with progression risk emphasizes the specific utility of sagittal skull measurements in comprehending adenoid-related outcomes. They provide evidence-based support for the integration of anterior-posterior cephalometric measurements into pediatric adenoid management algorithms.

DISCUSSION

The present study provides novel data on the interaction of skull size patterns and adenoid hypertrophy in children and determines anterior-posterior diameter as a useful predictor of adenoid severity and progression to severe obstruction. The findings contribute to the growing literature supporting the contributions of craniofacial morphometry to adenoid pathophysiology and clinical management.[13] The high frequency of transverse dimensional patterns in 71.3% of the patients conforms to general principles of normal craniofacial growth, where lateral growth tends to outpace sagittal expansion during childhood which aligns with Kim *et al.*[14] The incremental increase in transverse dominance with advancing age, from 68% in the youngest age group to 80% in the oldest age group, is reflective of the natural curve of skull growth and maturation. This developmental pattern is relevant to the understanding of the spatial interaction between the adenoid tissue and the nasopharyngeal cavity because, in transverse expansion, there would be greater accommodation of lymphoid tissue without compromising the airway.[15] The close association of anterior-posterior diameter with adenoid severity, demonstrated by both correlation analysis and multinomial logistic regression, suggests that the sagittal dimension of the skull plays a cardinal role in adenoid pathophysiology. The incremental rise in anterior-posterior measurements from mild (112.2 mm) to severe (123.1 mm) adenoid hypertrophy, with the 22% increase in the likelihood of severe disease for every millimeter increase, offers a quantifiable association of skull morphometry with clinical severity.[16] This finding aligns with Hsia *et al.* reflecting a predisposing anatomical structure permitting adenoid enlargement.[17] Cox proportional hazards analysis provides highly significant prognostic information, with the anterior-posterior diameter independently predicting the time to progression to severe adenoid obstruction. The 12% increased hazard per millimeter increase in anterior-posterior diameter enables clinicians to stratify patients based on objective morphometric criteria, potentially enabling earlier intervention in high-risk individuals.[18] This prognostic capability is especially relevant given the significant morbidity of advanced adenoid obstruction, including sleep-disordered breathing, chronic rhinosinusitis, and potential impacts on cognitive development.[19] The absence of significant associations between transverse diameter and adenoid severity or progression contrasts with the strong predictive capability of anterior-posterior measurements. This differential association suggests that while transverse skull widening is the dominant growth pattern, it will not directly influence adenoid pathophysiology or clinical outcomes.[20] The larger transverse dimensions of the study sample (mean 126.2 mm versus 118.4 mm anteroposterior) possibly provide sufficient lateral space to accommodate adenoid tissue without functional compromise, whereas sagittal constraints may more directly impinge on airway patency.[21] Sexual variation in dimensional patterns, with transverse dominance being more frequent in females (73.7% compared to 57.1%), can reflect established sexual dimorphism in craniofacial development. These variations can have implications for gender-differentiated treatment strategies for adenoid management, though clinical relevance has to be established.[22] Similarly, the consistent predominance of the transverse patterns in all ages, despite the increasing incidence with age, suggests that dimensional preference is established early in development and maintained in childhood.[23] The clinical implications of these observations extend from diagnosis to treatment planning and prognosis. The ability to anticipate adenoid severity and potential for progression from readily available cephalometric measurements provides clinicians with objective tools for clinical decision-making.[24] Patients with larger anterior-posterior dimensions can be treated earlier or watched more closely, while those with predominantly transverse configurations are perhaps treated more conservatively.[25] The integration of digital radiographic techniques with cutting-edge morphometric analysis represents a significant enhancement in the evaluation of pediatric adenoid disease. The precision and reliability of digital measurements, along with the application of sophisticated statistical modeling, enable the determination of morphometric relationships with greater accuracy than has been achievable using conventional techniques.[26] These technological advancements enable the development of evidence-based approaches to adenoid management based on objective anatomic criteria rather than on subjective clinical judgment alone.

Limitations of the study

This Cross-sectional study design limits the establishment of causality between skull size and adenoid growth. Temporal associations cannot be reliably ascertained. The comparatively small sample size may limit generalizability to more heterogeneous pediatric groups with heterogeneous ethnic or geographic backgrounds.

CONCLUSION

The study demonstrates that the anterior-posterior diameter of the skull is a significant predictor of the risk of severity of adenoid hypertrophy and the development of severe obstruction in the pediatric population. Despite transverse dimensional patterns being common in normal skull development, sagittal measurements provide improved prognostic significance for adenoid pathology. The measurable relationship between anterior-posterior diameter and clinical function provides objective risk stratification and evidence-based therapeutic planning. These findings make cephalometric analysis an appropriate part of pediatric patient assessment for adenoid hypertrophy, with the likelihood of improving early detection of high-risk individuals and optimizing therapeutic intervention.

Recommendations

Following longitudinal studies should address the temporal relationship between skull dimensional growth and adenoid development to ascertain causality. Three-dimensional imaging techniques may provide more comprehensive morphometric evaluation and enhanced predictive validity for outcomes in the clinic.

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