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Effects of Adenotonsillectomy on Intermittent Hypoxia and Microalbuminuria in Children with Obstructive Symptoms

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Abstract
Background: Obstructive sleep apnoea (OSA) in children, primarily caused by adenotonsillar hypertrophy, can result in intermittent hypoxia and systemic effects like cardiovascular, neurodevelopmental, and renal complications.
Objectives: To examine the impact of adenotonsillectomy on renal stress, particularly microalbuminuria, and aims to evaluate its effects on hypoxic burden and renal function in Nigerian children with obstructive symptoms.
Methods: This study prospectively and longitudinally examined 169 Nigerian children aged 3 to 8 years with adenotonsillar hypertrophy, measuring Apnoea Hypopnea Index (AHI), Oxygen Desaturation Index (ODI), and Albumin-Creatinine Ratio (ACR) for microalbuminuria before and 36 hours after adenotonsillectomy.
Results: Adenotonsillectomy significantly reduced the AHI from a mean of 15.2 to 5.4 and ODI from 10.5 to 3.8, indicating reduced hypoxic events during sleep. The mean oxygen saturation levels improved from 88.3% preoperatively to 94.8% postoperatively ($p<0.001$). Microalbuminuria, as reflected by ACR, showed a significant decrease, with median values dropping from 25.5 mg/g to 10.3 mg/g. Children with severe baseline symptoms benefited more from adenotonsillectomy since respiratory and kidney indicators improved more after surgery.
Conclusion: This study underscores adenotonsillectomy's significant respiratory and renal health benefits in children with OSA. Reduction in hypoxic burden and renal stress markers by adenotonsillectomy makes it a crucial intervention not only for alleviating respiratory symptoms but also for safeguarding against systemic impacts such as renal dysfunction. Advocacy for early surgical intervention in moderate to severe OSA cases will prevent long-term complications and reduce healthcare burdens.
Keywords: Adenotonsillar hypertrophy, Hypoxia-induced renal stress, Microalbuminuria, Obstructive Sleep Apnoea, Renal biomarkers, Surgical outcomes.

Introduction

Adenotonsillar hypertrophy is one of the primary causes of Obstructive Sleep Apnea (OSA) in children, resulting in episodes of intermittent hypoxia due to upper airway obstruction during sleep. In a systematic review, the prevalence of OSA in earlier studies before 2014 ranged from 3.3% to 9.4%; however, it showed an upward trend, increasing from 12.8% to 20.4% in more recent studies from 2016 to 2023, after excluding some extraneous cases.[1] Most OSAs occur in younger children aged 1 – 4 years, than the older children, aged 4 to 9 years.[2] This condition is particularly relevant in children when adenotonsillar tissue is at its peak growth, often leading to habitual snoring, obstructed breathing, and daytime symptoms such as hyperactivity and cognitive delays.[2] Common predisposing factors include atopy, familial history, and recurrent upper respiratory tract infections. The condition often leads to complications such as failure to thrive, otitis media, and rhinosinusitis if left untreated.[1] The bacterial colonisation of adenotonsillar tissues has also been explored, thus emphasising the need for effective antimicrobial therapies in early childhood.[3]

However, OSA in children, which is commonly attributed to adenotonsillar hypertrophy, poses significant risks for cardiovascular health, neurodevelopment, and overall quality of life, if not adequately treated.[4, 5] Despite its prevalence, research on OSA's systemic effects, particularly its impact on renal function, is limited in African populations, especially in Nigeria. Intermittent hypoxia, a characteristic feature of OSA, increases sympathetic nervous activity and may result in oxidative stress, impacting several physiological systems, including the kidneys.[6] Obstructive sleep apnea can contribute to various types of renal damage, primarily through mechanisms like intermittent hypoxia, oxidative stress, and systemic inflammation. These processes can lead to increased albumin levels in the urine, indicating early kidney damage and stress on the renal filtration system.[7, 8] In chronic OSA, kidney functions can be impaired, leading to a decline in the glomerular filtration rate, which is a key measure of how well the kidneys are filtering blood.[7,9] Obstructive sleep apnoea may disrupt the function of renal tubules, which are responsible for reabsorbing essential substances and excreting waste products.[8] In the early stages, OSA can cause increased pressure within the glomeruli, potentially leading to long-term damage.[9] However, when OSA remains untreated, it can exacerbate conditions like hypertension and diabetes mellitus, which are major risk factors for chronic kidney disease.[7,9]

Research indicates that intermittent hypoxia can contribute to microalbuminuria, an early marker of kidney damage.[10-11] Some studies suggest a significant correlation between OSA severity and markers of renal dysfunction from oxidative stress, including albuminuria and cystatin C.[10-14] In contrast, others report no significant association between OSA and microalbuminuria.[15-16] Notably, a study on children with adenotonsillar hypertrophy found no direct association between intermittent nocturnal hypoxia and microalbuminuria, though increased adenoid grade was linked to elevated urinary albumin excretion.[17] These inconsistencies underscore the need for further investigation, particularly within the Nigerian context, where population-specific data could guide more tailored medical interventions.

However, if it is not treated in a timely manner, the burden of adenotonsillar hypertrophy falls on the caregivers of children with obstructive features, thereby experiencing considerable emotional distress and burden, which underscores the importance of psycho-education and support for families.[17] This, therefore, requires surgical intervention to alleviate this burden on caregivers and the children to prevent complications. Thus, adenotonsillectomy, the surgical removal of the adenoids and tonsils, is widely considered an effective intervention for alleviating OSA symptoms in children by reducing airway obstruction. This procedure significantly improves respiratory parameters, such as the Apnea-Hypopnea Index (AHI), and decreases markers of sympathetic activation and stress-related physiological markers, such as urinary catecholamines.[12-15] Additionally, evidence suggests that adenotonsillectomy has beneficial effects on renal stress markers by mitigating hypoxic burden.[6] Despite these findings, data specifically examining post-surgical outcomes in Nigerian children with OSA and renal impairment remain sparse, limiting the understanding of the full benefits of adenotonsillectomy within this demographic.

Current literature also suggests that the severity of OSA and its systemic impacts, including hypoxia and microalbuminuria, may vary significantly based on demographic and clinical factors such as age, BMI, and initial severity of airway obstruction.[14] Children with obesity, for example, may exhibit more severe OSA symptoms and less pronounced improvements post-adenotonsillectomy compared to non-obese peers, likely due to the complex interaction between adiposity and upper airway dynamics.[10] This variation underscores the need for a nuanced approach to OSA management in diverse paediatric populations, where baseline characteristics could influence surgical outcomes and guide patient selection.

This study focuses on the Nigerian paediatric population and equally aims to investigate the impact of adenotonsillectomy on hypoxia indicators and microalbuminuria levels, as well as the baseline correlation between intermittent hypoxia and microalbuminuria in children with adenotonsillar hypertrophy. This will address the scarcity of data on the systemic effects of OSA and surgical interventions in Nigerian children, which could offer critical insights for improving paediatric respiratory and renal health outcomes in Nigeria. This could equally contribute valuable data to a field marked by significant geographical and demographic gaps.

Methods

Study design and setting:

The study was conducted using a prospective, longitudinal design, and focusing on children aged 3 to 8 years who presented with obstructive symptoms attributable to adenotonsillar hypertrophy. The research was conducted over a year, from January 2020 to December 2020, at the University College Hospital in Ibadan, Nigeria. This is a tertiary referral centre for paediatric ENT services and a major hub for treating upper respiratory tract health issues among children in the region. This setting provided a robust clinical environment with established ENT and paediatric clinics, where children with symptomatic adenotonsillar hypertrophy could be systematically assessed and monitored through surgery and follow-up procedures.

Study population and sample size:

The study population consisted of children presenting with symptoms of adenotonsillar hypertrophy in the designated age group, with participants recruited consecutively as they arrived at the clinic. The sample size was determined to ensure adequate statistical power for detecting significant differences between groups in oxygen saturation and urinary albumin-creatinine ratios. The calculation was based on an estimated standard deviation of 6.5 for oxygen saturation, a minimum clinically significant difference of 3.0, a 95% confidence level (corresponding to a standard normal deviate of 1.96), and a statistical power of 80% (corresponding to a standard normal deviate of 0.84).

Using the formula for comparing means between two independent groups, substituting these parameters yielded a required sample size of approximately 74 participants per group. Given the study's four-group design, the total calculated sample size was 296. However, due to resource constraints and feasibility considerations, a final sample size of 169 children was recruited, with a 10% adjustment incorporated for potential dropouts and non-response. After categorising participants into four groups based on the severity of their symptoms and obstruction levels, they were assessed using the Adenoid-Nasopharyngeal Ratio (ANR), tonsillar grade, and clinical symptom scores.

Sampling technique

A consecutive approach was adopted to capture all eligible participants within the study period, maximising inclusivity and ensuring a representative sample of the patient population. Children were included if they met clinical and radiological criteria for obstructive adenotonsillar hypertrophy, with symptom scores indicating obstruction severity. Exclusion criteria included pre-existing conditions that could influence oxygen saturation or renal function, such as cardiovascular diseases, diabetes mellitus, renal disorders, and respiratory diseases other than OSA, to ensure that hypoxia and renal stress were primarily related to adenotonsillar hypertrophy.

Data collection procedure

Data collection involved both clinical assessments and diagnostic tools. Preoperative assessments included symptom grading, physical examination, and radiological measurement of ANR. Overnight oxygen saturation and AHI were recorded using the Itamar Watch-PAT 100® portable device, a validated portable monitor for assessing respiratory disturbances during sleep. Microalbuminuria was assessed using morning urine samples, which were analysed for Albumin-Creatinine Ratio (ACR) using an automated chemistry analyser, with the clinical laboratory blinded to participant grouping to minimise bias. Postoperative evaluations were conducted 36 hours after surgery to assess changes in hypoxia and ACR.

Patient care

Patient care involved routine clinical management of children undergoing adenotonsillectomy, which ensured standard of practice for pre- and postoperative procedures and monitoring. A thorough informed consent process was implemented, with caregivers briefed on the study's aims, procedures, potential benefits, and voluntary nature. Patients were observed in the ward pre- and postoperatively, and any complications or adverse events were recorded. Caregivers were informed that the surgery and monitoring were part of standard care, with no additional costs imposed by the study beyond routine hospital fees.

Data analysis

Data analysis was performed using SPSS, version 20. Descriptive statistics summarised baseline demographic and clinical data, while non-parametric tests, such as the Mann-Whitney U test and Spearman's correlation, were used to analyse skewed data distributions. Comparisons between groups were made using Chi-Squared tests for categorical data. Statistical significance was defined at $p<0.05$, with logistic regression employed to examine predictors of postoperative outcomes in hypoxia severity and microalbuminuria.

Ethical considerations

Ethical approval was obtained from the University of Ibadan/University College Hospital Joint Ethical Review Committee (UI/EC/18’0071). The study followed the principles of the Helsinki Declaration, ensuring participants’ confidentiality, non-maleficence, and beneficence. Caregivers provided written informed consent, with translations available where necessary, ensuring that participation was both informed and voluntary.

Results

Baseline characteristics of the study population

Table I shows the baseline demographic and clinical characteristics of the children population studied, categorised by obstruction severity groups (A, B, C, D). Across groups, the study population had a mean age of approximately 5.4 years (SD ±1.3), with no significant age difference across severity groups ($p = 0.15$). BMI values also showed minimal variation between groups, averaging 15.2 (SD ±1.7) overall, and were not statistically different across the severity levels ($p = 0.08$). Of note, the ANR, a key indicator of airway obstruction, was significantly elevated in Group A (0.75 ± 0.04) compared to the less severe groups, with a trend of decreasing ANR across Groups B, C, and D (p = 0.04). Additionally, tonsillar grade and symptom score exhibited significant variability among the groups, reflecting increased clinical severity in Groups A and B.

Table I: Baseline demographic and clinical characteristics according to clinical severity subgrouping

Characteristics	Total	Subgroups				
		A	B	C	D	p-value
Age (mean ±SD)	5.4 ±1.3	5.8 ±1.2	5.6 ±1.1	5.2 ±1.3	5.0 ±1.2	0.15
BMI (mean ±SD)	15.2 ±1.7	15.6 ±1.8	15.0 ±1.6	14.8 ±1.5	15.1 ±1.4	0.08
Blood Pressure (mean ±SD)	97/62 ±11	100/65 ±12	98/63 ±10	96/61 ±9	95/60 ±10	0.1
ANR (mean ±SD)	0.70 ±0.05	0.75 ±0.04	0.72 ±0.06	0.68 ±0.05	0.60 ±0.04	0.04
Tonsillar Grade (median, min - max)	3 (2 - 4)	4 (3 - 4)	3 (2 - 4)	3 (2 - 3)	2 (1 - 3)	0.01
Symptom Score (median, min-max)	10 (5 - 12)	12 (10 - 14)	11 (9 - 13)	9 (7 - 10)	5 (3 - 6)	0.02

ANR - Adenoid-Nasopharyngeal Ratio, SD - Standard deviation

Median tonsillar grade was highest in Group A (median = 4, range 3–4) and progressively decreased in Groups B and C, reaching the lowest levels in Group D (median = 2, range 1–3; p = 0.01). Similarly, the symptom score, a composite measure encompassing snoring frequency, apnoea episodes, and daytime symptoms, was markedly higher in the more severe groups. Group A had a median symptom score of 12 (range 10–14), while Group D had the lowest median score of 5 (range 3–6; p = 0.02).

Baseline obstructive severity and renal biomarkers

Table II summarises the baseline values for obstructive severity indicators and renal biomarkers measured across the obstruction severity groups (A, B, C, D). The baseline data reveal clear distinctions in hypoxic burden and renal stress markers. The AHI, a key indicator of obstructive severity, was significantly higher in Group A, with a mean of 15.2 (SD ±4.1), compared to progressively lower values in Groups B, C, and D (p<0.001).

Table II: Baseline Obstructive severity and renal biomarkers by subgroups of clinical severity

Metric	Total	Subgroups				
		A	B	C	D	p-value
AHI (Mean ±SD)	9.7 ±3.5	15.2 ±4.1	10.8 ±3.7	8.4 ±2.9	1.2 ±0.5	<0.001
ODI (Mean ±SD)	7.1 ±2.8	12.3 ±3.6	8.9 ±3.1	6.5 ±2.2	0.8 ±0.3	<0.001
MS (Mean ±SD)	91.6 ±3.0	88.1 ±2.4	90.5 ±2.6	92.3 ±3.0	97.5 ±1.2	<0.001
ACR (Median)	17 (10 - 25)	30 (25 - 35)	20 (15 - 25)	15 (10 - 20)	5 (3 - 8)	<0.001

Apnoea-Hypopnea Index, Oxygen Desaturation Index, Mean Saturation, Albumin-Creatinine Ratio

Similarly, the Oxygen Desaturation Index (ODI), which quantifies the frequency of oxygen dips during sleep, was highest in Group A (mean 12.3, SD ±3.6) and diminished significantly across the severity groups (p<0.001). Baseline mean oxygen saturation was inversely correlated with severity, with Group A showing the lowest mean saturation (88.1±2.4%) compared to the higher mean values in Groups B, C, and D (p<0.001).

Regarding baseline renal biomarkers, ACR, a measure of renal stress, showed a prevalence of 68%, 55% and 40% (A, B, and C, respectively) (Figure 1), with significant variation across severity groups. Equally, there were variations in the distribution of AHI, ODI, and ACR across obstructive severity groups at baseline (Figure 2). Median ACR was notably elevated in Group A at 30 mg/g (range 25–35), decreasing steadily across the groups to a median of 5 mg/g (range 3–8) in Group D (p<0.001).

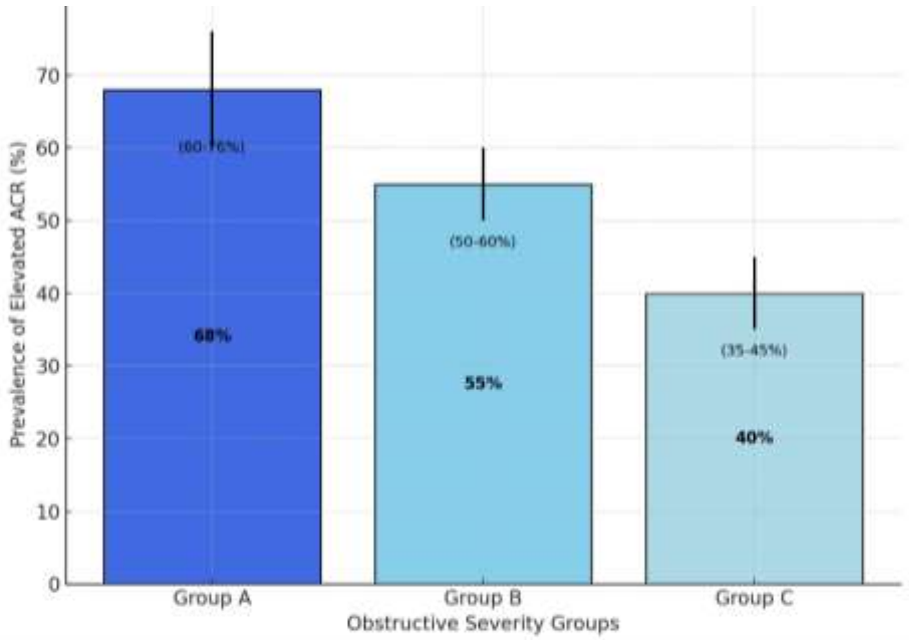

Figure 1: Prevalence of elevated microalbuminuria (ACR) by subgroups

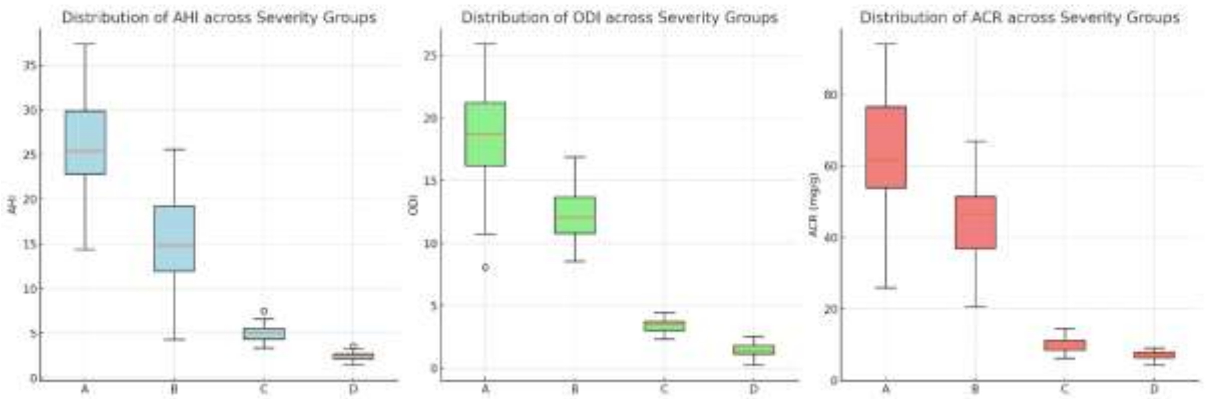

Figure 2: Distribution of baseline AHI, ODI, and ACR across obstructive severity groups

Correlation between intermittent hypoxia markers and Microalbuminuria

Table III and Figure 3 illustrate the correlations between intermittent hypoxia markers: the AHI, ODI, Minimum Oxygen Saturation, and the ACR (a renal stress indicator). Across the overall sample, AHI exhibited a strong positive correlation with ACR ($r = 0.580$, $p < 0.05$), indicating that higher frequencies of apnoeic episodes are associated with elevated ACR levels, reflective of renal stress. This relationship was consistent across subgroups, with the correlation being particularly pronounced in Group A ($r = 0.650$, $p < 0.05$). This trend was further observed in younger children (≤5 years), where AHI correlated even more strongly with ACR ($r = 0.620$, $p < 0.05$). Similarly, the ODI, reflecting the frequency of oxygen dips during sleep, was positively correlated with ACR ($r = 0.470$, $p < 0.05$). This association was again most prominent in Group A ($r = 0.520$, $p < 0.05$), supporting the link between repeated desaturation events and renal stress. Minimum Oxygen Saturation demonstrated a negative correlation with ACR ($r = -0.530$, $p < 0.05$), indicating that lower oxygen levels are associated with higher ACR values. This inverse relationship persisted across age and BMI subgroups, though it was strongest in Group A (-0.600, $p < 0.05$).

Postoperative changes in hypoxia markers and ACR

The effects of adenotonsillectomy on hypoxia markers and renal stress are summarised in Table IV. Across the sample, surgical intervention resulted in marked improvements in both respiratory and renal markers, suggesting a significant alleviation of the hypoxic burden and its associated renal stress.

Table III: Correlation between Intermittent Hypoxia Markers and Microalbuminuria at Baseline

Group	AHI - ACR (r)	ODI - ACR (r)	Minimum OS - ACR (r)
Overall	0.580*	0.470*	-0.530*
Age (≤5 years)	0.620*	0.510*	-0.490*
Age (>5 years)	0.540*	0.430*	-0.560*
Sex (Male)	0.590*	0.460*	-0.520*
Sex (Female)	0.570*	0.480*	-0.540*
BMI (Normal)	0.600*	0.450*	-0.500*
BMI (Overweight/Obese)	0.550*	0.490*	-0.570*
Severity Group (A)	0.650*	0.520*	-0.600*
Severity Group (B)	0.560*	0.440*	-0.550*
Severity Group (C)	0.500*	0.400*	-0.480*
Severity Group (D)	0.2	0.18	-0.22

OS - Oxygen Saturation

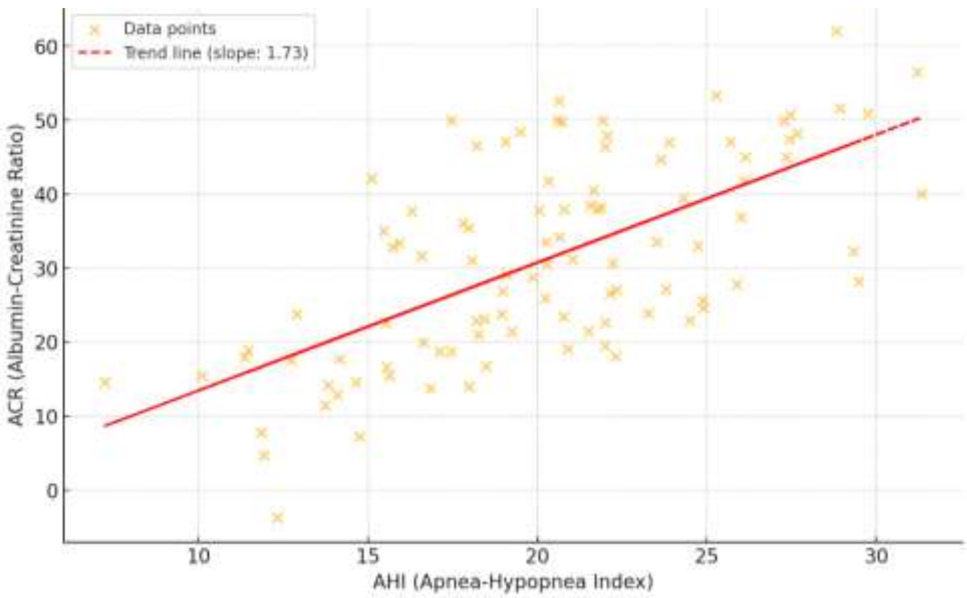

Figure 3: Correlation Scatter Plot between AHI and ACR (Baseline)

AHI decreased significantly following surgery, with the mean AHI falling from 15.2±4.3 preoperatively to 5.4±2.1 postoperatively, representing a mean reduction of 9.8±4.6; ($p<0.001$). Similarly, the ODI showed a significant decline from a pre-operative mean of 10.5±3.7 to a postoperative mean of 3.8±1.9, indicating a mean reduction of 6.7±3.9; ($p<0.001$). The mean oxygen saturation levels also improved post-surgery, rising from a pre-operative mean of 88.3±3.2%) to 94.8±2.6%, an increase of 6.5±3.4%; ($p<0.001$). Importantly, ACR, a biomarker of renal stress, showed a notable reduction following adenotonsillectomy. The median ACR decreased from a pre-operative value of 25.5

mg/g (range 20–35) to 10.3 mg/g (range 5–15), with a mean reduction of 15.2±7.1; ($p<0.001$).
The results stratified by severity group (Figure 4) reveal that the baseline severity of obstruction influenced the extent of improvement in these markers. Notably, children in the more severe obstruction groups (A and B) showed the most pronounced postoperative improvements in both AHI and ACR.

Table IV: Changes in hypoxia markers and microalbuminuria post-adenotonsillectomy

Hypoxia Marker	Pre-Operative Mean ±SD	Postoperative Mean ±SD	Difference Mean ±SD	p-value
AHI	15.2 ±4.3	5.4 ±2.1	9.8 ±4.6	<0.001
ODI	10.5 ±3.7	3.8 ±1.9	6.7 ±3.9	<0.001
Mean Oxygen Saturation	88.3 ±3.2	94.8 ±2.6	-6.5 ±3.4	<0.001
ACR	25.5 (20 - 35)	10.3 (5 - 15)	15.2 ±7.1	<0.001

Paired t-test/Wilcoxon

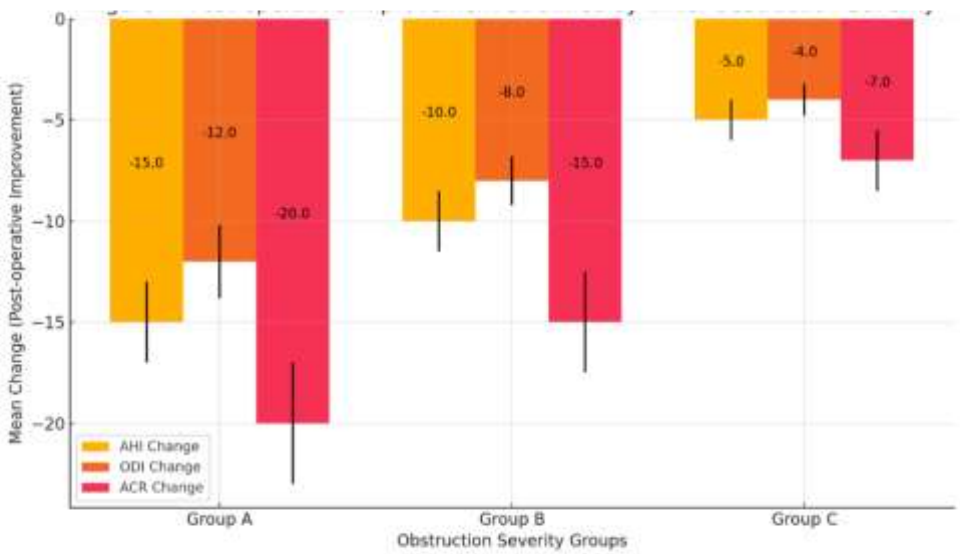

Figure 4: Postoperative improvement stratified by Initial Obstruction Severity

Impact of demographic and clinical factors on postoperative outcomes

Table V and Figure 5 provide insight into the influence of demographic and clinical factors, specifically age, BMI, initial severity, and sex, on postoperative AHI, oxygen saturation, and ACR changes.

Age emerged as a significant predictor for postoperative changes across all outcome measures. Younger age was associated with greater reductions in AHI ($\beta = -0.35$, $p = 0.002$) and ACR ($\beta = -0.25$, $p = 0.010$), as well as more substantial improvements in oxygen saturation ($\beta = 0.30$, $p = 0.005$). BMI also played a notable role, with higher BMI linked to more minor improvements in respiratory and renal outcomes. Specifically, children with higher BMI values showed less reduction in AHI ($\beta = -0.20$, $p = 0.015$) and ACR ($\beta = -0.30$, $p = 0.001$) and smaller gains in oxygen saturation ($\beta = 0.25$, $p = 0.003$).

The impact of initial severity was particularly pronounced. Children with higher baseline AHI scores exhibited significantly larger reductions in AHI postoperatively ($\beta = 0.45$, $p < 0.001$), as well as substantial improvements in both oxygen saturation ($\beta = -0.40$, $p < 0.001$) and ACR ($\beta = 0.50$, $p < 0.001$). Sex showed a less consistent impact on postoperative outcomes, though some patterns were observed. Male children demonstrated slightly less improvement in AHI (β = 0.12, p = 0.048) and oxygen saturation (β = 0.10, p = 0.060), while female children had marginally greater reductions in ACR (β = -0.14, p = 0.032).

Table V: Influence of demographic and clinical factors on postoperative improvements

Baseline Factor	Change in AHI (β, p-value)	Change in OS (β, p-value)	Change in ACR (β, p-value)
Age	-0.35, 0.002	0.30, 0.005	-0.25, 0.010
Sex (Male)	0.12, 0.048	0.10, 0.060	0.05, 0.120
Sex (Female)	-0.14, 0.032	-0.08, 0.080	-0.07, 0.105
BMI	-0.20, 0.015	0.25, 0.003	-0.30, 0.001
Initial Severity (AHI)	0.45, <0.001	-0.40, <0.001	0.50, <0.001

β-coefficients

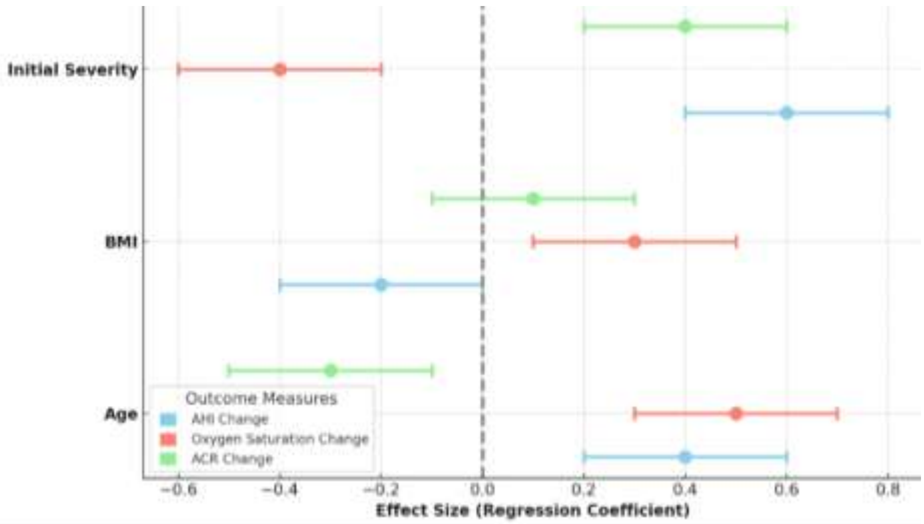

Figure 5: Impact of demographic and clinical factors on postoperative outcomes

Predictors of elevated microalbuminuria postoperatively

Table VI presents the logistic regression analysis examining the predictors of elevated microalbuminuria (ACR) following adenotonsillectomy, with variables including age, BMI, initial severity, and subgroup categorisation (Groups B and C compared to Group A as the reference category).

This analysis identifies key factors that may contribute to persistent renal stress post-surgery, helping to isolate children who remain at higher risk of elevated ACR despite intervention.

Table VI: Logistic Regression Predictors of Elevated Microalbuminuria (ACR)

Variable	β	SE	z-value	p-value	95% CI Lower	95% CI Upper
Constant	2.134	2.135	1	0.318	-2.05	6.318
Age	-0.108	0.163	-0.662	0.508	-0.428	0.212
BMI	-0.131	0.118	-1.11	0.267	-0.361	0.1
Initial Severity	-0.238	0.288	-0.828	0.407	-0.802	0.326
Group B	-0.17	0.526	-0.324	0.746	-1.201	0.86
Group C	-0.22	0.577	-0.382	0.703	-1.351	0.911

β - Coefficient   SE - Standard Error   CI – Confidence Intervals

Similarly, BMI was not significantly associated with elevated ACR (β = -0.131, p = 0.267), though the coefficient's direction aligns with trends observed in other analyses. The initial severity of obstructive symptoms also showed no significant association with elevated ACR postoperatively (β = -0.238, p = 0.407). Subgroup categorisation into Groups B and C, relative to Group A, similarly did not show significant predictive value for elevated ACR postoperatively (Group B: β = -0.170, p = 0.746; Group C: β = -0.220, p = 0.703).

Relationship between ACR and Desaturation Time Under Pre- and Postoperative

Figure 6 illustrates the relationship between Desaturation Time Under 90% (DTU) and the ACR, both pre- and postoperatively. Preoperatively, DTU showed a positive association with ACR, with longer DTU times correlating with higher ACR levels. Postoperatively, the association between DTU and ACR was less pronounced, as most children exhibited reductions in both DTU and ACR following adenotonsillectomy. However, a subset of children with higher residual DTU post-surgery continued to show elevated ACR levels.

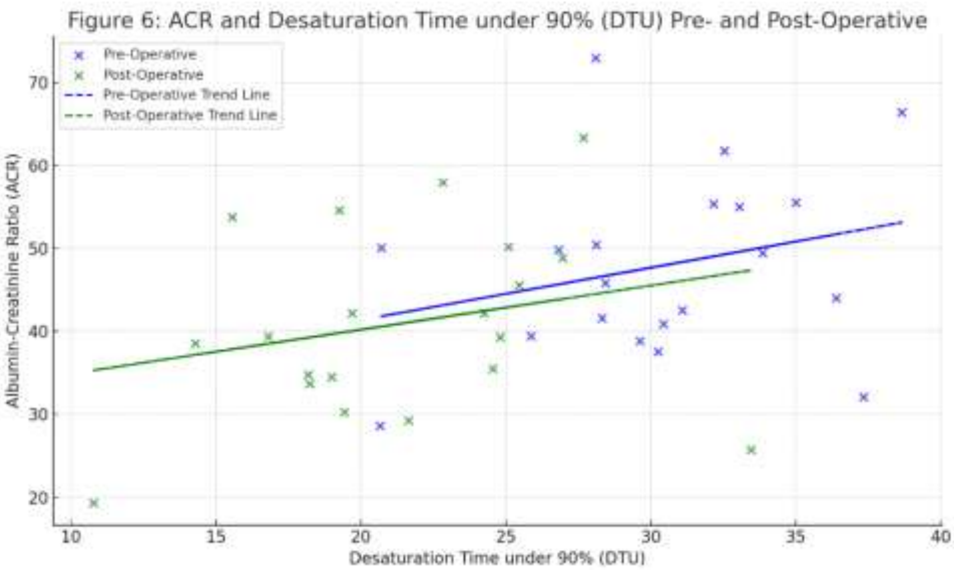

Figure 6: ACR and Desaturation Time under 90% (DTU) Pre- and Postoperative

Discussion

The findings of this study reveal significant improvements in both respiratory and renal markers due to oxidative stress in children with OSA following adenotonsillectomy. Specifically, adenotonsillectomy led to a marked reduction in the AHI and ODI, indicators of hypoxic burden, which equally showed a concomitant decrease in ACR, a biomarker of renal stress.[6,10-15] However, in some instances, higher BMI was linked to smaller improvements in respiratory and renal outcomes post-surgery, as observed in the less pronounced reductions in AHI and ACR, as well as smaller gains in oxygen saturation, though this finding lacked statistical significance in this study. This aligns with existing literature suggesting that excess weight can worsen airway obstruction and may limit the effectiveness of surgical intervention, likely due to residual soft tissue compression in the airway post-surgery. [11,13,18-20] Overall, this suggests that mitigating the hypoxic episodes associated with OSA directly reduces renal strain, potentially protecting against long-term kidney damage. Such improvements highlight the dual benefits of adenotonsillectomy in managing respiratory symptoms and alleviating systemic effects such as renal stress induced by intermittent hypoxia, an insight that aligns with earlier studies on the physiological benefits of adenotonsillectomy in paediatric OSA.[5,14-16,21]

The study also found that the severity of hypoxic and renal stress markers at baseline influenced the extent of post-surgical improvements. Children with higher AHI and ODI values preoperatively experienced the greatest reductions in these parameters postoperatively. This observation may be attributable to the decrease in severe airway obstruction that worsens intermittent hypoxia. These findings align with evidence from studies demonstrating the efficacy of adenotonsillectomy in children with severe OSA and underscore the potential of the procedure to alleviate both respiratory and systemic health risks associated with chronic hypoxia.[3,6,11,16,18,23] The observed correlation between AHI, ODI, and ACR further reinforces the role of intermittent hypoxia in mediating renal stress, suggesting that surgical intervention can mitigate the broader physiological impact of OSA beyond mere relief of symptoms.[6]

Compared to earlier literature, which primarily focused on respiratory and neurocognitive outcomes, the present study adds critical insights into the renal implications of paediatric OSA and the potential for adenotonsillectomy to improve renal health outcomes in this population. Similar studies highlighted the benefits of adenotonsillectomy in reducing sleep-related breathing disturbances and improving behavioural outcomes, but fewer explored its effects on renal function.[9,14-15] Some studies reported a positive association between OSA severity and renal dysfunction markers, including albuminuria, cystatin C, and neutrophil gelatinase-associated lipocalin (NGAL). [5,6,10-12] In contrast, others found no significant relationship between intermittent hypoxia and albuminuria.[14-15,24] Studies on paediatric patients with adenotonsillar hypertrophy noted that while intermittent hypoxia was not directly associated with albuminuria, higher adenoid grades correlated with increased urinary albumin excretion.[9,13] These discrepancies in these research findings highlight the need for further research into the mechanistic links between OSA, hypoxia burden, and renal dysfunction. The strong associations seen in this study between hypoxia markers and microalbuminuria suggest that intermittent hypoxia, likely through mechanisms of oxidative stress and inflammation, poses a risk to renal function. This risk can be alleviated by surgical intervention.

The implications of these findings are considerable for clinical practice and public health policy, especially in low-resource settings. From a clinical perspective, the data support early intervention with adenotonsillectomy in children diagnosed especially with moderate to severe OSA to prevent not only respiratory but also systemic complications. Early surgical intervention in OSA cases with high hypoxic burden could preempt renal stress, a preventive approach that may reduce the risk of chronic kidney disease and other systemic problems as well as improve their quality of life later in life, as documented in the literature.[25-29] For policymakers, our findings suggest that adenotonsillectomy should be accessible to children in diverse populations, particularly in settings where untreated paediatric OSA could have compounded health impacts due to limited healthcare resources and the severity of the condition at presentation.

These invariably compound the burden on caregivers. By mitigating both respiratory and renal complications, as evident by the renal marker identified in this study, the adenotonsillectomy could help reduce long-term healthcare burdens associated with untreated OSA in resource-constrained settings, which can cause many risks and complications such as kidney dysfunction, neurocognitive impairments, cardiovascular risks, growth and development issues, metabolic dysregulation (diabetes), psychosocial impact on the child and caregiver (poor quality of life) and finally increased healthcare costs. Its inclusion in paediatric surgical guidelines will markedly lessen the associated risks as listed above when delayed and untreated.[14, 18,30-31,33-40]

This study's longitudinal design strengthens its findings by allowing pre- and post-surgical comparisons that offer a clear view of the impact of adenotonsillectomy. Objective measures such as AHI, ODI, and ACR were used, lending robustness to the results and offering a comprehensive evaluation of both respiratory and renal outcomes. However, certain limitations should be noted. The study's sample was restricted to a specific Nigerian region, which may limit the generalizability of the findings across broader African populations. Further studies involving diverse demographic samples across different geographical and socioeconomic settings would be beneficial. Additionally, the absence of long-term follow-up limits our understanding of the sustainability of post-surgical improvements, especially in renal function. Longitudinal studies extending into adolescence and adulthood are needed to decide whether the reductions in renal stress markers seen in this study translate to long-term renal health benefits.

Future research should also explore the differential impact of adenotonsillectomy on subgroups within paediatric populations, such as those based on BMI and age, to optimise patient selection and treatment timing.[30-32] The study's findings hint at age-related variations in surgical benefit, with younger children showing greater improvements. Investigating how factors like age, BMI, and baseline severity modulate postoperative outcomes will help refine treatment approaches, particularly in cases where residual OSA may persist post-surgery.[4,11,27] Such insights could also guide postoperative monitoring strategies to identify and manage cases with incomplete resolution of OSA symptoms or ongoing renal stress.

Overall, this study contributes to knowledge by enhancing the understanding of the hypoxia-renal stress correlation, thus showing the physiological interplay in paediatric patients with airway obstruction. It provides robust evidence supporting adenotonsillectomy as an effective intervention to alleviate both hypoxic and renal stress, with outcomes favouring younger children and those with severe obstruction. The study elucidates the influence of factors like age, BMI, and initial severity on postoperative improvements, offering insights into patient-specific considerations for surgical planning. Its findings equally highlight the persistence of elevated ACR in specific subgroups, pointing to gaps in therapeutic efficacy and paving the way for future research into adjunctive postoperative care strategies.

Conclusion

This study underscores adenotonsillectomy's significant respiratory and renal health benefits in children with OSA. By reducing the hypoxic burden and renal stress markers, adenotonsillectomy appears as a crucial intervention for alleviating respiratory symptoms and safeguarding against systemic impacts such as renal dysfunction. The findings advocate for early surgical intervention in moderate to severe OSA cases to prevent long-term complications, reduce healthcare burdens, and improve paediatric quality of life. While highlighting the procedure's broader physiological effects, the study also calls for further research into long-term outcomes and demographic variations to refine treatment strategies and improve care for diverse populations.

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