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RESEARCH ARTICLE

ADENOID HYPERTROPHY: A CORRELATION OF RADIOGRAPHIC PARAMETERS TO POSTOPERATIVE ADENOID VOLUME

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Abstract

Background: Various objective parameters of assessing adenoid size on x-ray have been proposed with no agreement on which is most suitable. In this study, the correlation of two radiographicparameters: adenoidal-nasopharyngeal ratio (ANR) and antroadenoid diameter (AA diameter) to postoperative adenoid volume were compared, with a view to determine which is more accurate.
Objectives: To determine and compare the correlations of ANR and AA diameter to postoperative adenoid volume, in order to establish which parameter is more accurate in assessing adenoid size on x-ray.
Methods: A cross-sectional analytical study conducted at the Moi Teaching and Referral Hospital, Kenya. 107 patients below fifteen years of age who had adenoid hypertrophy and underwent subsequent adenoidectomy were enrolled.Correlation was calculated using Pearson's correlation,controlling for the number of days between x-ray and surgery, which was a potential confounding factor. Comparison of the two correlation coefficients was carried out using Steiger's Z-test.
Results: The age of the participants ranged from 11 months to 11 years. The mean ANR was 0.70, mean AA diameter was 3.10mm while the mean postoperative adenoid volume was 2.83mL.Correlation of the ANR to the postoperative adenoid volume was0.661($p<0.001$) while that of the AA diameter was -0.222 ($p=0.022$).Null hypothesis was tested using Steiger's Z-test and the difference between the two correlation coefficients found to be significant.The ANR is, therefore, determined to have a stronger correlation to postoperative adenoid volume than the AA diameter.
Conclusion: ANR is a better predictor of adenoid volume than the AA diameter.

Introduction:-

Adenoid hypertrophy is a common clinical condition especially among children, with adenoidectomy being one of the most frequently performed ear, nose and throat (ENT) surgical procedures(Oburra& Idenya, 2001). Left untreated, adenoid hypertrophy can lead to complications including cor pulmonale, otitis media and in severe cases

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of chronic mouth breathing, craniofacial distortion in what is termed “adenoid facies”(Elluru, 2005), thus the need for timely accurate diagnosis and management.

Owing to their location in the nasopharynx, it is difficult to assess the adenoids clinically hence the need for imaging. Lateral radiographs of the neck are commonly used to assess adenoid size, especially in the developing world, as they are easily accessible and readily available (Kolo et al., 2011). However, despite their frequent use, there is no consensus on how the size of the adenoids should be measured on x-ray (Major et al., 2006).

Various objective parameters of measuring adenoid size on x-ray have been put forth. The adenoidal-nasopharyngeal ratio (ANR) is one such measureproposed by Fujioka, Young and Girdanyin 1979(Fujioka et al., 1979). Using the ANR the size of the adenoid is measured relative to the nasopharynx. Different authors have found measurement of the ANR to be useful,includingKemaloglu, Inal, Goksu and Akyildiz (1999), who found the ANR to be of more value in determining whether the adenoids were clinically significant or not when compared to the absolute size of the adenoids or the nasopharynx(Kemaloglu et al., 1999). This finding was supported by Gangadhara, Rajeshwari and Jain in 2012 in a study on 100 children to determine the significance of using the ANR to evaluate adenoid hypertrophy in children(Gangadhara et al., 2012). Use of the ANR has, nevertheless, been criticized as involving cumbersome calculations since two measurements are made then a ratio computed, which is likely to increase interobserver variability(Jeans et al., 1981).

Other authors, however, advocate for measurement of the degree of narrowing of the nasopharyngeal airway when assessing adenoid size on x-ray. One such measure is the antroadenoid diameter (AA diameter) put forward by Hibbert and Whitehouse in 1978(Hibbert & Whitehouse, 1978). The AA diameter is measured as the narrowest distance between the adenoids and the posterior wall of the maxillary antrum which lies on the same plane as the posterior choanae. Hibbert and Stell in 1979 found the antroadenoid diameter to be significantly different between children scheduled to undergo adenoidectomy and normal controls when compared to the absolute size of the adenoids (Hibbert & Stell, 1979). Crepeau, Patriquin, Poliquin and Tetreault backed these findings in a study in 1982, where the antroadenoid diameter was determined to have a stronger correlation to a symptomatology score for adenoid hypertrophy ($r=-0.34$, $p<0.005$) when compared to the diameter of the adenoids ($r=0.27$, $p<0.02$) (Crepeau et al., 1982).

The antroadenoid diameter has, however, been found to be less sensitive in evaluating the size of the adenoid tissues in a number of studies. Jeans, Fernando and Maw in 1981 carried out a study correlating several measurements of the adenoid size on x-ray to the volume of adenoid tissues postoperatively,where the correlation of the antroadenoid diameter was0.28($p<0.1$) while that of the ANR was 0.51 ($p<0.01$)(Jeans et al., 1981). In addition, some authors have cautioned against measurement of the nasopharyngeal airway on x-ray arguing that the nasopharynx is a more complex three-dimensional structure than the adenoid, thus loses more information when compressed to a two-dimensional image(Major et al., 2006).

There is, therefore, need to determine which method of assessing the size of the adenoids onx-ray is more accurate. This study aims to achieve that by comparing the correlation of the ANR and AA diameter to the volume of the adenoid tissues measured postoperatively.

Hypothesis:

The null hypothesis is that there is no difference between the correlation coefficient of ANR to postoperative adenoid volume (r_1) and the correlation coefficient of AA diameter to postoperative adenoid volume (r_2).

$$r_1 = r_2$$

The alternative hypothesis is that there is a difference in the correlation coefficient of ANR to postoperative adenoid volume (r_1) and AA diameter to postoperative adenoid volume (r_2).

$$r_1 \neq r_2$$

Methods:-

Study design and sample size:

This cross-sectional analytical study was carried out at Moi Teaching and Referral Hospital, Kenya, for a period of one year from September 2017 to August 2018. Patients aged fifteen and below who had adenoid hypertrophy and were scheduled to undergo surgery were recruited. Exclusion criteria included patients with a history of previous adenoidectomy and patients with craniofacial anomalies that alter the morphology of the nasopharynx such as cleft palate and Down's syndrome. Sample size was calculated using the formula for studies involving the difference in two correlation coefficients described by Hulley, Cummings, Browner, Grady & Newman, 2013(Stephen B. Hulley et al., 2007).A sample of 107 participants was obtained.

X-ray imaging protocol:
X-rays were taken using a digital x-ray machine with the patient lying in supine position and the lateral aspect of the head in contact with the Bucky grid. The head was adjusted so that the median sagittal plane was parallel to the Bucky grid placing the patient in true lateral position. Images were taken with the mouth closed. Exposure factors of 70 kilovolts and 3.2 milli-ampere seconds. A source-to-image distance of 140cm was applied. Digital images were used to take the measurements on x-ray to avoid errors due to magnification.

Measurements on lateral radiograph of the neck:
The size of the adenoids on x-ray was measured using two parameters: the ANR and AA diameter.

Using the ANR, the size of the adenoids is measured relative to the size of the nasopharynx. A line, B, is drawn along the anterior margin of the basiocciput. The size of the adenoids, A, is measured from the point of maximal convexity of the shadow of the adenoid along a line perpendicular to B. The depth of the nasopharynx, N, is measured from the posterosuperior margin of the hard palate to the anteroinferior margin of the spheno-basioccipital synchondrosis. The ANR is then determined by dividing the size of the adenoids (A) by the depth of the nasopharynx (N). This is illustrated below.

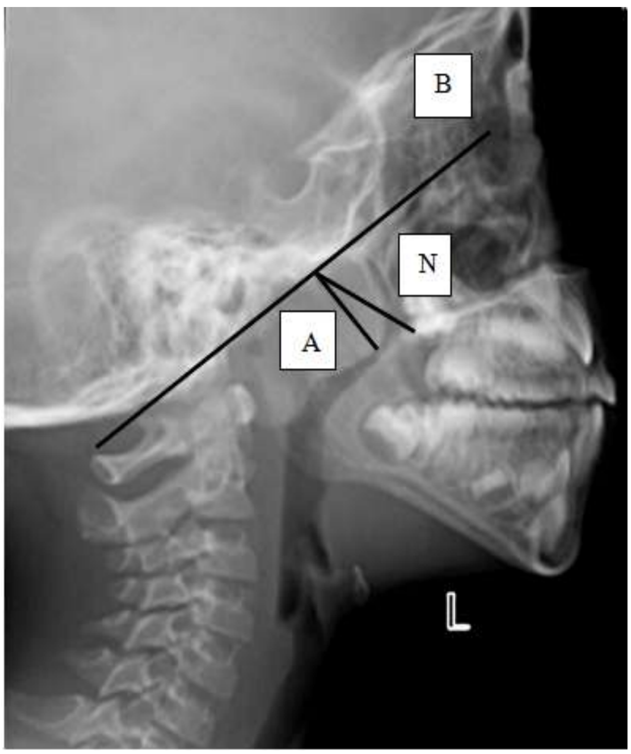


Figure 1:- Adenoidal-nasopharyngeal ratio.

The AA diameter is measured as the narrowest distance between the posterior wall of the maxillary antrum and the shadow of the adenoids. The posterior wall of the maxillary antrum is on the same level as the posterior choanae on a lateral radiograph of the neck. The AA diameter is illustrated as D using the red line below:

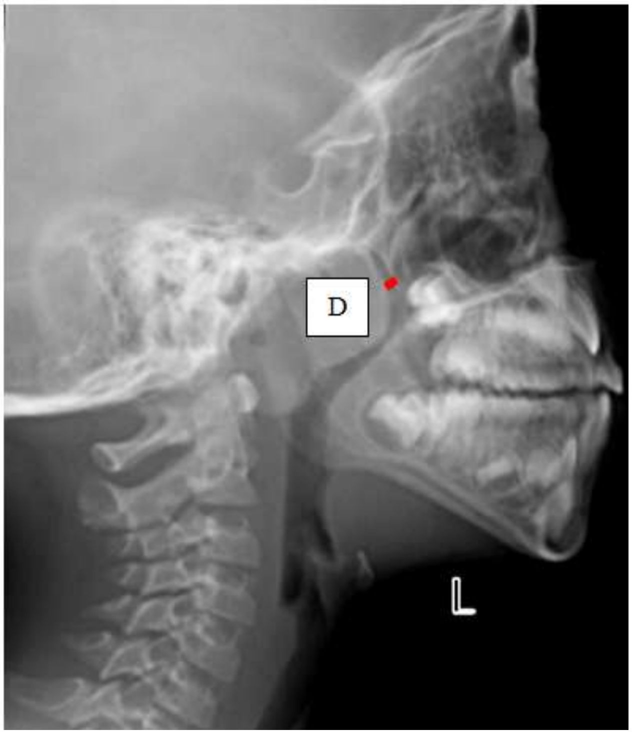
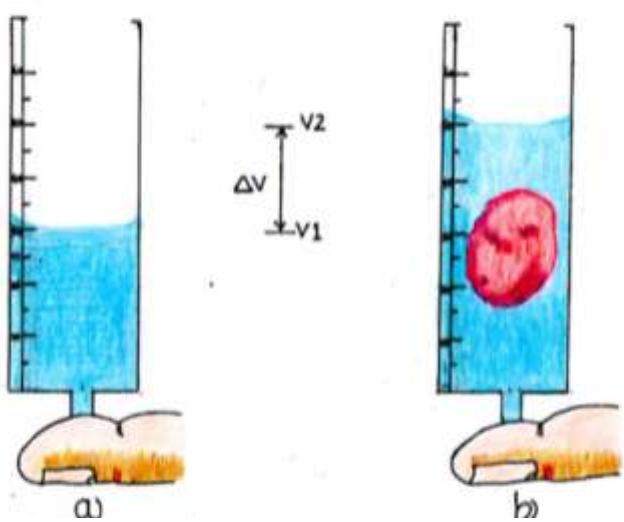


Figure 2:- Antroadenoid diameter.

Measurement of postoperative adenoid volume:
Adenoidectomies were done by ENT surgeons using the same technique of curettage adenoidectomy. The volume of the adenoids was measured immediately after adenoidectomy by a trained research assistant, an ENT theatre nurse, who was blinded to the findings on x-ray to avoid bias. The adenoids were first placed in a kidney dish containing normal saline to remove any residual blood and blood clots. The postoperative adenoid volume was then measured using the technique described in the article by Mason, Hehar, Holden and Jones (1995) of fluid displacement using a 20 mL syringe. Using this method, normal saline is placed into the syringe to a level (**v_1**)which is recorded. The plunger of the syringe is removed, and the nozzle capped off using a finger. The adenoids are then completely immersed into the normal saline and the level to which the saline is displaced is recorded (**v_2**). The final volume of the adenoids(**Δv**) is then calculated by subtracting the original volume of the normal saline in the syringe from the volume after immersing the adenoids.(Mason et al., 1995). This is demonstrated in **Figure 3** below:



$\Delta v = v_2 - v_1$

Figure 3:- Measurement of postoperative adenoid volume.

Data Analysis:
The correlations of the ANR and AA diameter to the postoperative adenoid volume were calculated using Pearson's correlation. Correlation was calculated controlling for the number of days between x-ray and surgery which was a potential confounding factor. The null hypothesis that there is no difference in the correlations of the ANR and AA diameter to the postoperative adenoid volume was tested using Steiger's Z-test. In all the analyses, a level of significance(α) of 0.05 was used thus a p-value of less than 0.05 was considered statistically significant.

Ethical Considerations:
Approval to conduct the study was obtained from the Institutional Research and Ethics Committee. Written informed consent was sought from the parents and/or guardians and assent from children above 7 years of age.

Results:-

Demographic characteristics:
A total of 107 participants were enrolled into the study.

The ages of the study participants ranged from 11 months to 11 years with a mean of 3.4 (± 2.0) years. Male children formed the majority at 72 (67.3%) with a male to female ratio of 2.1:1. The mean age of the female participants was 3.3 (± 1.8) years compared to that of that of the males at 3.4 (± 2.1) years; the difference in the mean ages of the male and female patients was not statistically significant. The majority of the patients were between 1 and 5 years of age.

Findings on x-ray and postoperative adenoid volume:
The findings on the radiographic parameters including ANR and AA diameter as well the postoperative volume of the adenoids areas summarized in **Table 1** below:

Table 1:- Findings on X-ray and Postoperative Adenoid Volume.

Variable	**Category**	**Mean (SD)**	**Min-Max**
X-ray	ANR	0.70 (0.16)	0.34-0.97
	AA diameter	3.10 (1.82)	0.20-8.40
Surgical	Adenoid volume	2.83 (1.20)	1.00-7.00
AA diameter: antroadenoid diameter, ANR: adenoidal-nasopharyngeal ratio, SD: standard deviation			

Correlation of radiographic parameters to postoperative adenoid volume:
Controlling for the number of days between x-ray and adenoidectomy, the correlation of the ANR to postoperative adenoid volume was positive and statistically significant at **0.661 ($p<0.001$)**while that of the AA diameter was negative and significant at **-0.222 ($p=0.022$).**

Comparison of the correlations of ANR and AA diameter to postoperative adenoid volume:
Comparing the absolute size of the two correlation coefficients $|r|$, that is 0.661 for the correlation of ANR to postoperative adenoid volume and 0.222 for the correlation of AA diameter, the ANR has a stronger correlation than the AA diameter.

To test the null hypothesis that there is no difference in the correlation of ANR to postoperative adenoid volume and the correlation of AA diameter to postoperative adenoid volume, Steiger's Z-test for correlated correlations was used as the two correlations share a common variable: postoperative adenoid volume. The absolute values of the correlation are used to calculate the Z-statistic using Steiger's test instead of the signed values, because we are interested in the strength of correlation that is, which of the two (ANR or AA diameter) is a significantly better predictor of adenoid volume. Thus 0.661 is used as the correlation coefficient of ANR to postoperative adenoid volume and 0.222 is used as the correlation coefficient of AA diameter to postoperative adenoid volume (instead of -0.222). Using the Steiger's Z-test, a Z-statistic is calculated using the formula (1) (Bivariate Correlation Comparisons, n.d.):

$$Z = Z_{12} - Z_{13} * \frac{\sqrt{(n-3)}}{\sqrt{2 * [1 - r_{23}] * h}} \quad \text{where, } h = 1 - \frac{[f * rm^2]}{1 - rm^2},$$

$$f = 1 - \frac{r_{23}}{2 * [1 - rm^2]} \quad \text{and} \quad rm^2 = {r_{12}}^2 + \frac{{r_{13}}^2}{2}.$$

where, r_{12} is the correlation of ANR to postoperative adenoid volume= 0.661
r_{13} is the correlation of AA diameter to postoperative adenoid volume=0.222
r_{23} is the correlation of ANR to AA diameter=0.28
Z_{12} is the Z transformation of r_{12}
and Z_{13} is the Z transformation of r_{13}

The Z-statistic calculated was Z=4.555, p<.05. This is larger than the Z-critical of 1.96 using a two-tailed test at a level of significance of 0.05. The null hypothesis is thus rejected, and it is determined that there is a significant difference between the correlation of ANR to postoperative adenoid volume and the correlation of AA diameter to postoperative adenoid volume.

It is thus concluded that the ANR is a better predictor of adenoid volume and the difference between the two correlation coefficients is significant.

Discussion:-

Lateral radiographs of the neck are commonly used to assess the size of the adenoids especially in the developing world, as they are easily accessible and readily available (Kolo et al., 2011). Several parameters on x-ray have been proposed with no consensus on how the adenoids should be measured. In this study, we compared the correlations of the ANR and the AA diameter to the postoperative volume of the adenoids with a view of determining which of the two parameters is more accurate.

Controlling for the number of days between x-ray and adenoidectomy, we determined the correlation of the ANR to the postoperative adenoid volume to be significant at 0.661 (p<0.001). This finding compares well with that in a study by Elwany (1987) who found a correlation of 0.66 (p<0.001) to adenoid weight(Elwany, 1987).Lertsburapa, Schroeder and Sullivan (2010) also found a correlation of 0.66 of the ANR to findings on intraoperative mirror examination (Lertsburapa et al., 2010). Our results, however, contrast those by Kolo et. al. (2011), where the correlation of the ANR to a symptomatology score was found to be weak and non-significant at 0.168(p=0.375)(Kolo et al., 2011).The disparity in results can be accounted for by difference in methodology where Kolo et. al. used a retrospective study obtaining data on symptomatology from patients' files. In addition, the ANR was measured on analog images using a transparent ruler which could have led to variation in results, compared to digital images used in this present study.

The correlation of the AA diameter in this study was significant at -0.222 (p=0.022). This agrees with results from a study by Maw, Jeans and Fernando (1981) who determined the AA diameter to have a correlation of -0.28 (p=0.049) to postoperative adenoid volume (Jeans et al., 1981). This was further echoed by Crepeau et. al. (1982) who determined the correlation of the AA diameter to a symptomatology score to be -0.34 (p<0.005)(Crepeau et al., 1982). Hibbert & Whitehouse (1978), on the other hand, obtained different results with a correlation of -0.78 (p<0.001) for the AA diameter(Hibbert & Whitehouse, 1978). Hibbert and Whitehouse correlated the $\log_{10}$ AA diameter to the $\log_{10}$ adenoid weight, which could explain the discrepancy in findings with our study.

Comparing the correlations of the ANR and AA diameter to postoperative adenoid volume; we determine that the ANR has a stronger correlation to the adenoid volume than the AA diameter and the difference between the two correlations is significant. Cho et al. (1999) obtained similar results with the ANR having a significant correlation of 0.604 (p<0.005) to adenoid size as measured using acoustic rhinometry when compared to that of the AA diameter which was non-significant at 0.286 (p=0.126)(Cho et al., 1999). Our findings also agree with a systematic review by Major et. al. (2006) who opined that measuring the degree of nasopharyngeal airway narrowing on x-ray is to be interpreted with caution as the nasopharynx is a more complex three-dimensional structure than the adenoid, thus tends to lose more information on a two dimensional image such as an x-ray(Major et al., 2006).

Orji and Ezeanolue (2008) also advocated for use of the ANR when assessing the adenoids onx-ray arguing that both the size of the airway and the size of the nasopharynx are taken into account when measuring the ANR(Orji &Ezeanolue, 2008). Mahboubi, Marsh, Potsic and Pasquariello (1985) in a study at a children's hospital, found variation in interpretation of the degree of narrowing of the airway between supine and erect radiographs of the same patient by observers, as the apparent dimensions of the airway changed depending on difference in the degree of extension of the neck and the position of the midline in relation to the plane of the film. Measurement of the ANR did not differ between supine and erect positions(Mahboubi et al., 1985).

Wormald and Prescott (1992), however, found differing results where the AA diameter was found to have a stronger correlation (r=0.22, p<0.05) to adenoid size as measured using endoscopy when compared to that of the ANR (r=0.11, p>0.5). The discrepancy in the results with this present study may be attributed to the difference in the methodology where there was double evaluation of 26 of the 48 patients before and after surgery in the study by Wormald and Prescott and the endoscopies were done by two observers, which may have contributed to variation in the results obtained(Wormald & Prescott, 1992).

In a study on 72 children aged below 11 years of age in Westmead, Australia, Waters et. al. (2013) found the ANR to have a lower correlation than the AA diameter. Differences in the method of comparison, where Waters et al. correlated the ANR and AA diameter to measurement of sleep variables using overnight polysomnography whereas in the present study the radiographic parameters were correlated to measurement of the volume of the adenoids postoperatively, could account for the variation in the results of the two studies. In addition, the measurements on x-ray in the study by Waters et. al. were taken by five observers of differing training including a sleep physician, ENT surgeon and registrar, a radiologist, and a research officer, which may have contributed to discrepancy in the measurements obtained. (Waters et al., 2013)

Conclusion:-

This study demonstrates a significant difference in the correlation of the ANR and the AA diameter to postoperative adenoid volume and determines the ANR to be a better predictor of adenoid volume than the AA diameter. We advocate for use of the ANR when assessing the size of the adenoids on lateral radiographs of the neck.

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