ADDIS ABABA UNIVERSITY
COLLEGE OF HEALTH SCIENCE, SCHOOL OF MEDICINE
DEPARTMENT OF DIAGNOSTIC RADIOLOGY

ASSESSMENT OF PEDIATRIC ADENOID SIZE AND ADENOID-TO-NASOPHARYNGEAL RATIO USING CONVENTIONAL CT AT TIKUR ANBESSA SPECIALIZED HOSPITAL (TASH) , ADDIS ABABA, ETHIOPIA
(PROSPECTIVE CROSS SECTIONAL STUDY)

Principal Investigator: TeferiGebrewahd (MD.)
Advisors: Dr. Daniel Zewdneh (Assoc Prof in Diagnostic Radiology)
Dr. Yocabel Gorfu (Asst Prof. in Diagnostic Radiology)

A thesis submitted in partial fulfillment for specialty certificate in Diagnostic Radiology

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Table 1: Definitions of abbreviations

Abbreviations	Definition
A	Adenoidal Diameter
AH	Adenoid Hypertrophy
ATH	Adenotonsillar Hypertrophy
ANR	Adenoid-to-Nasopharyngeal Ratio
CT	Computed Tomography
N	Nasopharyngeal space depth
PA	Palatal Airway
PNS	Post Nasal Space
SPSS	Statistical Package for social Science
TASH	TikurAnbessa Specialized Hospital
UAO	Upper Airway Obstruction
VNP	Video Nasopharyngoscopy
WHO	World Health Organization

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Article summary

Background information: Many studies have been developed revealing normal measurements of adenoid size and adenoid to nasopharyngeal Ratio (ANR). The lateral radiograph is a common investigative modality. However, the literature is diverse and controversial. Lateral x-rays undertaken for purposes other than suspected upper airway way obstruction at Tikur Anbessa Specialized Hospital (TASH) are assumed to be inadequate for the sample size needed for this study. Moreover, the risk of radiation exposure makes the use of lateral x–ray requests solely for this study unethical. Therefore a cross-sectional imaging study was done.

Objective: To determine the accurate size of the mean adenoidal size and ANR

Methodology: A quantitative prospective cross-sectional study was conducted in 114 patients aged from 4-12 years (divided into three age groups), who underwent CT of the neck or head & neck at Tikur Anbessa Specialized Hospital (TASH), Addis Ababa, Ethiopia. Subjects who had symptoms of upper airway obstruction or sleep-disordered breathing were excluded objectively using Obstructive Sleep Apnea score (OSA). Linear measurements of adenoid size and nasopharyngeal depth were done along a reconstructed sagittal section and the ANR was calculated according to the Fujioka method.

Results:

We studied 114 children aged 4-12 years who were divided into three sub-groups namely group I (4-6 yrs), II (7-9 yrs) and III (10-12yrs). We calculated the mean adenoid thickness, mean nasopharyngeal depth and calculated the mean ANR of each groups. The statistically analyzed mean ANRs were 0.416, 0.397 and 0.395 for Group I, II, and III respectively with the highest value of 0.66 detected in group I. The mean adenoid size were measured to be 8.34, 8.41, and 9.42 for the age groups I, II and III respectively. We found that both the mean adenoid size and the ANR did not show significant differences between each groups but there was a progressive increase of the nasopharyngeal depth as the age progress across the different groups.

Conclusion:

Adenoid to nasopharyngeal ratio (ANR) was the most consistent radiologic parameter when subjectively compared with previous x-ray based studies. Therefore we strongly recommend the use of ANR rather than the mere use of the adenoid size or the nasopharyngeal space depth particularly when evaluating the degree of nasopharyngeal obstruction by enlarged adenoids. However radiologists and responsible physicians should use lateral x-rays cautiously as plain

films may overestimate or underestimate the adenoid shadow and nasopharyngeal space depth due to superimposition of adjacent structures.

CHAPTER ONE

INTRODUCTION

1.1 BACK GROUND INFORMATION

Adenoids are a mass of lymphoid tissue found in the nasopharynx. The adenoids start their development from the 3rd pharyngeal arch during the 3rd month of embryogenesis; they become completely formed by the 7th months (1). Capitanio and kirpatrick stated that the adenoid shadow is often seen in infants aged 6 month and older on imaging.

The adenoids have been observed to become evident by six months to one year of life. They then rapidly increase in size during the first 6-8 years of life after which they regress in size, from childhood to adulthood (3).

Adenoidal hypertrophy, which was first described by Danish physician in 1868, is the unusual growth of the adenoids and is often caused by predisposing factors such as repeated infections. Wilhelm Meyer explained that chronic adenoid hypertrophy results in nasal airway obstruction, and that the obstruction is a factor of the size of the adenoids and the size of the nasopharyngeal airway. Surgical removal of the hypertrophied tissue, often carried out alongside tonsillectomy, can be required to alleviate symptoms that resulted from a compromise in the patients with Adenoid hypertrophy.

Physicians usually rely on the history and physical examination to determine whether there is a clinically significant Adenoid Hypertrophy or not. Although grossly enlarged adenoids may be diagnosed easily, physical examinations provide little information about the size of the adenoids. Therefore imaging becomes important for the assessment of patients with suspected Upper Airway Obstruction (UAO) secondary to Adenoid Hypertrophy.

There are several methods that aimed at objectively assessing imaging modalities used in the evaluation of adenoid size. However, interpretation of the imaging modalities has been very subjective. This study was done to have a more standardized and accurate mean adenoid size and Adenoid to Nasopharyngeal Ratio (ANR) of children in different age groups so that it can be used as a local reference by radiologists before diagnosing Adenoid Hypertrophy.

1.2 Literature review

*1.2.1*Radiological assessment

Accepted international methods for the assessment of Adenoid Hypertrophy include: Clinical scoring system, lateral neck radiography, and videonasoparyngoscopy (VNP). Despite several suggested methods of adenoid size evaluation, there is little agreement on the most ideal techniques used (Table 1)

Table 2: Different techniques for evaluation of adenoid hypertrophy

Fujioka et al.	ANR: measures the distance of the adenoid at its greatest diameter, against the size of the nasopharyngeal space
Cohen et al.	AC:SP measures the size of the air column in the nasopharynx, 10mm from the hard palate, against the soft palate thickness at the same level
Johannesson et al.	NpT (mm): measures the greatest width of the adenoid tissue perpendicular to the bony roof of the nasopharynx
Mlynarek et al.	AO: measures the Johannesson dimension against the width of the nasopharynx
Crepeau et al.	AA: measures the shortest width between the adenoid tissue and the posterior maxillary wall
Maw et al.	PA: measures the shortest width from anterior adenoid to the soft palate

*1.2.1.1 **Adenoid to nasopharyngeal ratio (ANR)***

According to a systematic review done by Feres et al (4) showed Adenoid to Nasopharyngeal ratio (ANR) was mentioned as the most frequently tested proportional measurement. Authors that used the ANR indicated that it was a more objective method having a high correlation with degree of obstructive symptoms.

The ANR, first proposed by Fujioka et al (5) in 1979, described the ratio between the maximum adenoid tissue thickness (defined by the distance between anteroinferior sphenobasioccipit and the most convex part of the adenoid tissue) and the nasopharyngeal depth (defined by the distance between the sphenobasioccipit and posterior edge of the hard palate). Linder-Aronson (6) used similar ratio and emphasized the importance of the ratio in obstruction symptoms due to adenoid tissue hypertrophy before Fujioka et al (5).

Fujioka et al calculated the ANR of 1,398 children using lateral radiographs of nasopharynx. He stated that for practical purposes ANR greater than 0.80 may be considered suggestive of Adenoid hypertrophy. He also found that the mean ANR increased from 0.55 at the age 1year 3 months, and reached its highest value, 0.59, at age 4 years 6 months, and then decreased to 0.52 at the age of 12 years and 6 months.

Similarly, in a study conducted on 100 children, Gangadhara et al (7) concluded that patients with ANR greater than 0.7 can be considered candidates for surgery. He calculated the mean ANR for the age groups 4-6, 7-9 and 10-12 to be 0.75, 0.73 and 0.60 respectively. The study also showed that the adenoid size increase during in the age group of 7 through 9 years and decrease in the age groups of 10through 12 years. According to the study there was no significant difference between the first two age groups in terms of the mean ANR but both groups had significant difference in the mean ANR compared with the third group.

1.2.2 Clinical assessment

There are many methods developed to clinically diagnose and grade Adenoid Hypertrophy but the most commonly used method was developed by Brouilete et al (8) in 1984. This method was initially developed for the diagnosis of obstructive sleep apnea in children and included the symptoms of difficulty in breathing during sleep (D), sleep apnea (A) and snoring (S). The method scored the symptoms as; Never (0), occasionally (1), frequently (2) and Always (3). A score of zero if absent or one if present was given for sleep apnea. The final score was calculated as follows:

$$1.42D + 1.41A + 0.71S - 3.83$$

Accordingly the final score were categorized as;

Mild if less than -1 and is equivalent with absence of OSA,
Moderate if between -1 and 3.5 and is suggestive of suspicious OSA and
Severe if greater than 3.5 and is diagnostic of OSA.

The clinical data of the patients included in the study of Fujioka et al. was not documented; therefore it was not clear as to whether the patients had symptoms of Upper Air way Obstruction (UAO). In order to avoid such ambiguity, the presence or absence of those symptoms and signs were asked in the form of a questionnaire to make sure that only patients with score less than -1 were included in our study.

Naushaba et al (9) concluded that those clinical scores maintained respectable values in grades of adenoid hypertrophy.Therefore the authors believe that such clinical screening will increase the accuracy of the study considering the main purpose of determining the normative value of the radiological parameters.

1.2.3 ***SIGNIFICANCE OF THE STUDY***

Adenotonsillar hypertrophy has been shown to be the most common cause of obstructive sleep apnea (OSA) in children (10) and the prevalence was stated to be 57.7 % on a recent study by Bitar et al in 2009 (11) . As one can expect considering the prevalence of the problem, adenotonsillectomy is among the top ten pediatric surgical procedures performed (22).

Patients who are not treated properly may develop long term complications including obstructive sleep apnea, recurrent otitis, failure to thrive, cor pulmonale and craniofacial abnormalities pulmonary hypertension; therefore early diagnosis and treatment of adenoid hypertrophy is very important. A prompt management of ATH can be facilitated by increasing the diagnostic accuracy of imaging modalities which will also depend on objective assessment of the adenoid size and the degree of nasopharyngeal obstruction.

The Fujioka method of measuring ANR correlated well with the clinical assessment score and weight of adenoids removed at operation in a study carried out by Feres et al (4). But before radiologists start diagnosing Adenoid Hypertrophy, the normal mean values of the adenoid size and Adenoid to Nasopharyngeal ratio (ANR) should be determined.

In spite of being the gold standard, VNP is expensive and not available to majority of the population; play radiographs remain non invasive and easily available imaging modalities in Ethiopia. This is also true for Tikur Anbessa Specialized Hospital (TASH). But for the purpose of attaining the minimum required sample size and radiation exposure issues, radiographs are not ethical for this study. Therefore, the mean adenoidal size and ANR of pediatric patients, who undergo conventional CT of the head/neck for purposes other than upper airway obstructions as a result of ATH, will be determined according to Fujioka method. In addition to the purpose of avoiding unnecessary radiation exposure only for the sake of research purpose, the adenoid-to-nasopharyngeal ratio (ANR) obtained through lateral radiographs has its own disadvantage because of superimposing of multiple anatomic structures. K. Lertsburapa et al (12) believed that the ANR calculated from lateral radiograph had tendency to overestimate or underestimate the adenoid size in comparison with nasal endoscopy. He also stated that radiologist's accuracy in assessing the ratios could be variable. The increased number of patients who undergo CT and Neck for many different purposes and those previously mentioned reasons we decided to determine the radiological parameters on cross sectional imaging.

As far as our knowledge is concerned, there are only few related studies which have used cross sectional imaging to evaluate the adenoid size and nasopharyngeal patency. The study conducted by Oh et al. using CBCT (Cone Beam Computed Tomography) reported that children with high ANR presented with obstructive adenoids (13). It is believed our study is going among those few articles studied using cross sectional imaging modalities

TASH is the largest and busiest hospital in the country where patients come from every corner of the nation and we firmly believe that our patients can represents the population of the country. This study reveals a more accurate normative data of adenoid size and ANR that can be used as a local reference as well as for the remaining medical society all over the world.

CHAPTER TWO

OBJECTIVES

2.1 **General objectives**

To determine the normal mean adenoid size and mean ANR of different pediatric age groups who underwent CT of the Neck or Head & Neck for purposes other than upper airway obstruction at Tikur Anbessa Specialized Hospital (TASH).

2.2 **Specific objectives**

- To determine the variations of mean adenoid size in relation to gender and age of different pediatric groups at TASH.
- To find out variations of adenoid size & ANR among different pediatric age groups at TASH.
- To subjectively compare results with previous x-ray based studies done by determining adenoid size & ANR on post nasal radiographs

CHAPTER THREE

METHODS AND MATERIALS

3.1 Study area

Study was done at Tikur Anbessa Specialized Hospital (TASH), Department of Diagnostic Radiology

3.2 Study period

The study was conducted from July 30, 2018 – July 30, 2019

3.3 Study design

Quantitative prospective cross-sectional study

3.4 Population

3.4.1 Source population

Pediatric patients who visited Tikur Anbessa Specialized Hospital from Ju1y 30, 2018-July 30, 2019

3.4.2 Study population

Children aged 4-12 who underwent CT of the Neck or Head & Neck at TASH

3.5 Inclusion and exclusion criteria

- **Inclusion criteria**
  - Children, both male and female, aged 4-12 yrs
  - No diagnosis of suspected upper airway obstruction
  - Underwent CT of the Neck or Head and neck at Tikur Anbessa Specialized Hospital (TASH)
- **Exclusion criteria**
  - Symptom and signs of upper airway obstruction secondary to adenoid hypertrophy (assessed objectively by standard questionnaire)

- Obvious deformities such as cleft lip &/palate or any evidence of mass which compromise the upper airway such as polyps or sinonasal tumors
- Medical history of Adenotonsillar surgery

3.6 Sample size

Sample size determination was done using GPower 3.1 and was also confirmed manually by calculating the sample size based on the modified formula required for comparing two independent means as described below.

n =16 S2/d2 + 1

Where d stands for the expected difference in the mean of the groups and S is the in group standard deviation

3.7 Sampling technique

Non random consecutive sampling method was used to recruit subjects who fulfill the criteria and for whom consent was obtained from the patient's parents or attendant until the calculated sample size was reached.

In our study the largest effect size, which provided the minimum sample size, was calculated from previous literature published by Gangadhara et al (7). Accordingly the expected mean difference of the adenoid size of patients in group 2 (7-9 years) and group 3 (10-12 years) of the study was used. Because the in group standard deviation of both groups was not known, an approximated common standard deviation was calculated from the same study by subtracting the lowest value from the highest value of adenoid size in the same age groups and dividing it by four.

Effect size = Expected mean difference/ In group standard deviation
= 3.36-3.08 / 4-2.3/4
= 0.28 / 0.425
= 0.6588
= 0.66

Applying the above effect size and other input parameters (alpha value = 0.05, power = 0.80, Allocation ratio (n1/n2) = 1 and Two tail test) on GPower 3.1 software, a total of 114 patients (38 patients per group) was needed for the study.

A similar result was also found using the modified formula for comparing independent means by applying the same parameters

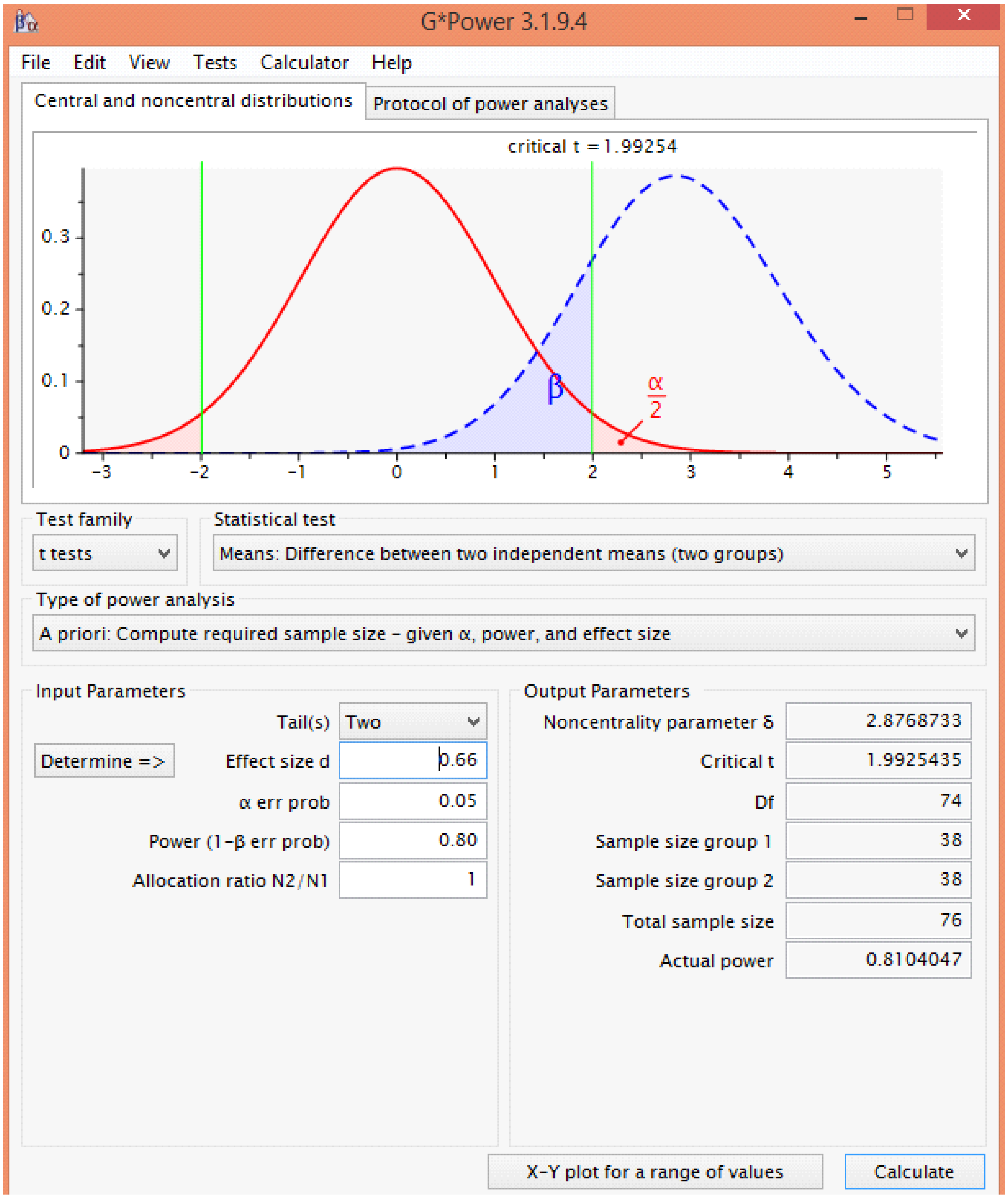
n =16 S2/d2 + 1

Where d stands for the expected difference in the mean of the groups and S is the in group standard deviation

= 16 (0.28 x 0.28) / (0.425 x 0.425) + 1
= 16 (0.180625) / (0.0784) + 1
= 16 (2.3) + 1
= 36.86 + 1
= 37.86
= 38

Accordingly a total of 114 patients, 38 patients per group, were taken as the most appropriate sample size included in our study.

Figure 1: Sample Size calculation using G*Power software (Version 3.1.9.4)



3.8 Variables

- 1 Independent
    - Age
    - Sex

- Dependent
    - Adenoid size (A)
    - Nasopharyngeal space depth (N)
    - Adenoid-to-nasopharyngeal space ratio (ANR)

3.9 Study procedure

3.9.1 Data collection instruments

3.9.1.1 Conventional CT of the Neck or head & neck

Conventional CT of the Neck or the Head & Neck was done at TikurAnbessa Specialized Hospital (TASH). The subjects were supine and were asked not to swallow, breath, or move the head or tongue. The subjects were also instructed to wear a thyroid collar while the CT is performed. All conventional CT images were obtained using the pediatric protocol. The 3D images were transformed to the DICOM (Digital Imaging and Communications in Medicine) format and reconstructed with the application of RadiAnt DICOM viewer software.

3.9.1.2 Questionnaire

Besides socio-demographic profiles, i.e. the age and sex of the patient, the questionnaire addressed standard questions, which were originally used to evaluate obstructive sleep apnea (OSA) in children, as well as the degree of mouth breathing

The questionnaire were administered by the principal investigator, responsible resident in the Neuro-radiology unit and radiology technologist in the CT room to the patient’s primary care giver citing the degree to which the indicated symptoms were present. A tick on the description options that best corresponded to the child condition was put.

The purpose of the questionnaire is to rule out upper airway obstruction secondary to adenoid hypertrophy. Only patients with clinical score of less than -1 and no sign of mouth breathing will be included in our study so that the subjects will be a fair representation of the normal population.

3.10 Data collection method

CT of the Neck or the Head and Neck of the sample population was taken. A linear radiological measurement of the adenoid size was done on a sagittal reconstructed image, from the most convex part of the lymphoid tissue perpendicular to a line that passes through the anterior sphenobasioccipital junction. Similarly, the nasopharyngeal airway depth was measured from the posterior end of the hard palate to a perpendicular line that passes through the anterior sphenobasioccipit junction on sagittal reconstructed images. ANR of each subjects were calculated by dividing their adenoid size by their respective nasopharyngeal depths.

The CT of each participant was analyzed by the principal investigator .The advisors reviewed and confirmed the radiologic assessment in the case of ambiguous situations or doubt before inclusion of the data into the study.

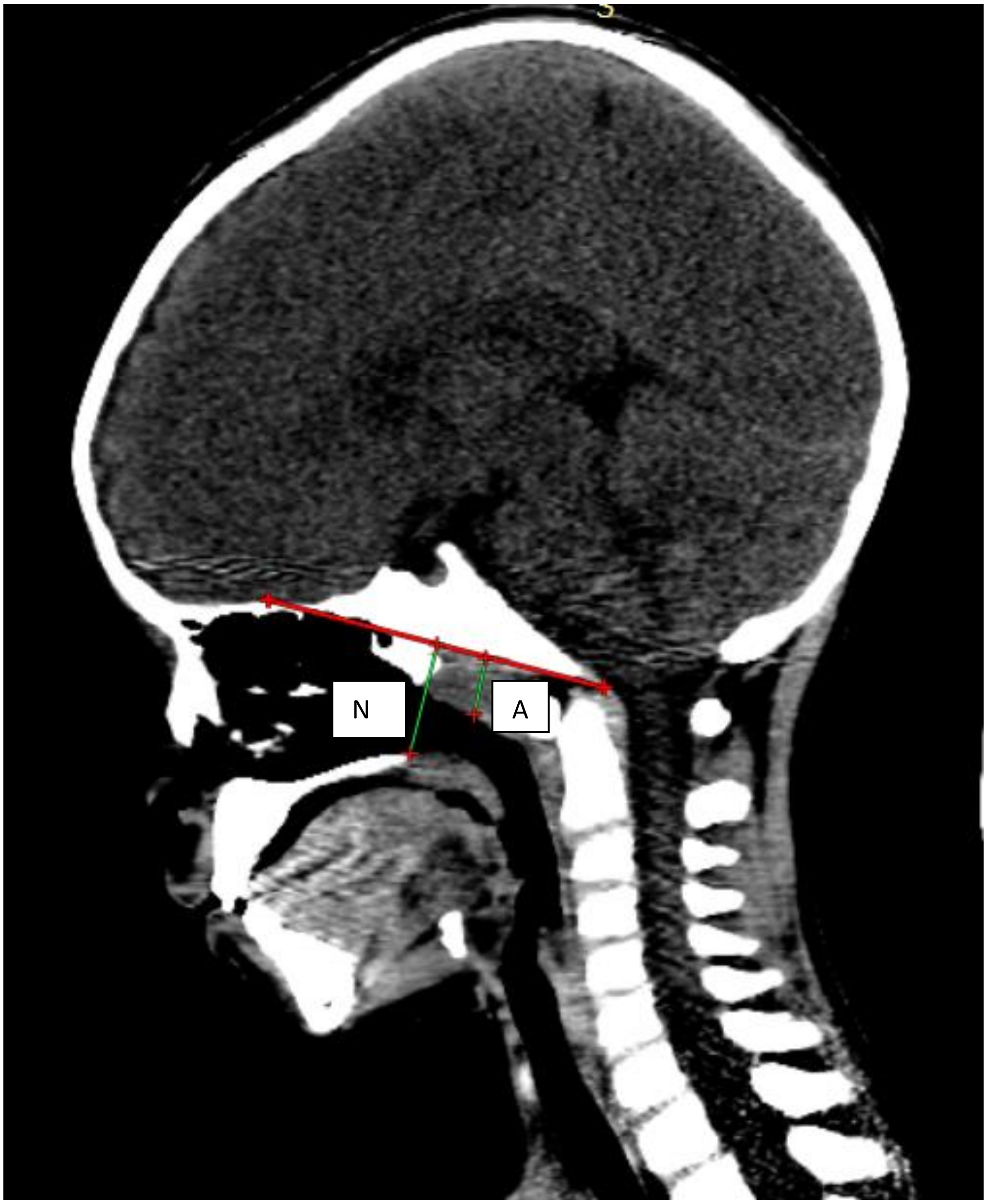


Figure 2 Sample picture from collected data; A refers to the distance between the outer most convexity of the adenoid shadow and the sphenobasioccipit measured perpendicular to a line drawn along the inner surface of the sphenobasioccipit(Red line) and N Shows the distance between the posterior end of the hard palate and sphenobasioccipit measured similarly to the adenoid size i.e. perpendicular to a line drawn along the inner surface of the sphenobasioccipit (Red line)

3.11 Data analysis

Statistical analysis was done using SPSS (version 25). Chi square was used to examine statistical associations between child attributes (independent factors) and the radiologic parameters with 95% confidence interval. Results are presented using tables and figures.

3.12 Data quality assurance and management

Data collectors were briefed on how to measure the radiologic parameters and on each items included in the questionnaire by the principal investigator. During data collection, the principal investigator clarified any ambiguity raised in the process and checked for the completeness and accuracy of the information before feeding the raw data into the computer was done.

3.13 Ethical consideration

Patients' records were kept confidential and all data were used only for the sake of the research. Identification of a record will only be possible through numerical codes. The patient's name, religious background and ethnicity will not be required for this study.

The study adhered to the ALARA (As Low As Reasonably Achievable) principle of radiation exposure.

An informed consent from each patient's parents or guardian was taken.

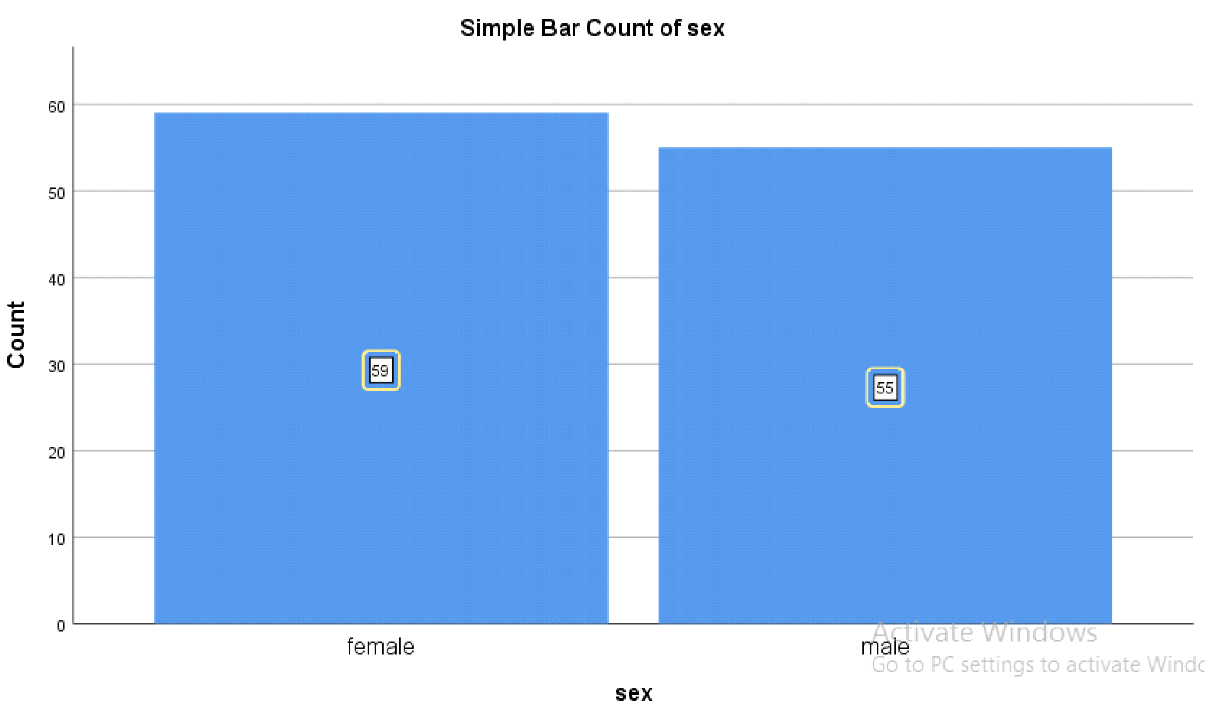
CHAPTER FOUR

4.1. Results and Observations

The adenoid size and nasopharyngeal space depth of 114 children aged 4-12 years, divided into three sub-groups namely group I (4-6 yrs), II (7-9 yrs) and III (10-12yrs), with no evidence of upper airway obstruction were recruited. The mean adenoid thickness, mean nasopharyngeal depth and calculated the mean ANR of each groups was calculated. The data was statistically analyzed using Chi-square and Independent sample t-test with SPSS software (version 25). $P < 0.05$ was considered to be statistically significant.

There were a total of total 114 patients of which 59 were females (51.8 %) and 55 were males (48.2%), which showed that there was no significant difference in the overall sex distribution (Chi square =140 ,P= 0.708, Figure 3).

Figure 3. Bar graph showing sex distribution within sample population
(Sept 25, 2019, Addis Ababa University, Addis Ababa Ethiopia)



The mean age was 98.24 and 94.47 months for females and males respectively and the independent sample t-test showed there is no significant gender difference in the mean age (t=615, p=.540)

Sex	Age groups I	II	III
Female	**20 (52.6%)**	**17 (44.7%)**	**22 (57.9%)**
Male	**18 (47.4 %)**	**21 (55.3 %)**	**16 (42.1 %)**
Total	**38 (33.33 %)**	**38 (33.33 %)**	**38 (33.33 %)**

Table 3. Sex distribution among each group
(Sept 25, 2019, Addis Ababa University, Addis Ababa, Ethiopia)

The mean adenoid size measured 8.7695 mm (Std. Deviation=2.71098) and 8.9500 mm (Std. Deviation=2.50845) among all females and males, that are included in the study, respectively. The mean adenoid to nasopharyngeal ratio measured .4010 (Std. Deviation=.10566) and .4050 (Std. Deviation=.9499) for both females and males respectively. The frequency distribution of the adenoid size, nasopharyngeal space depth and adenoid to nasopharyngeal ratio followed expected curves for normal distribution and there was no significant difference between female and male patients ($P > 0.05$).

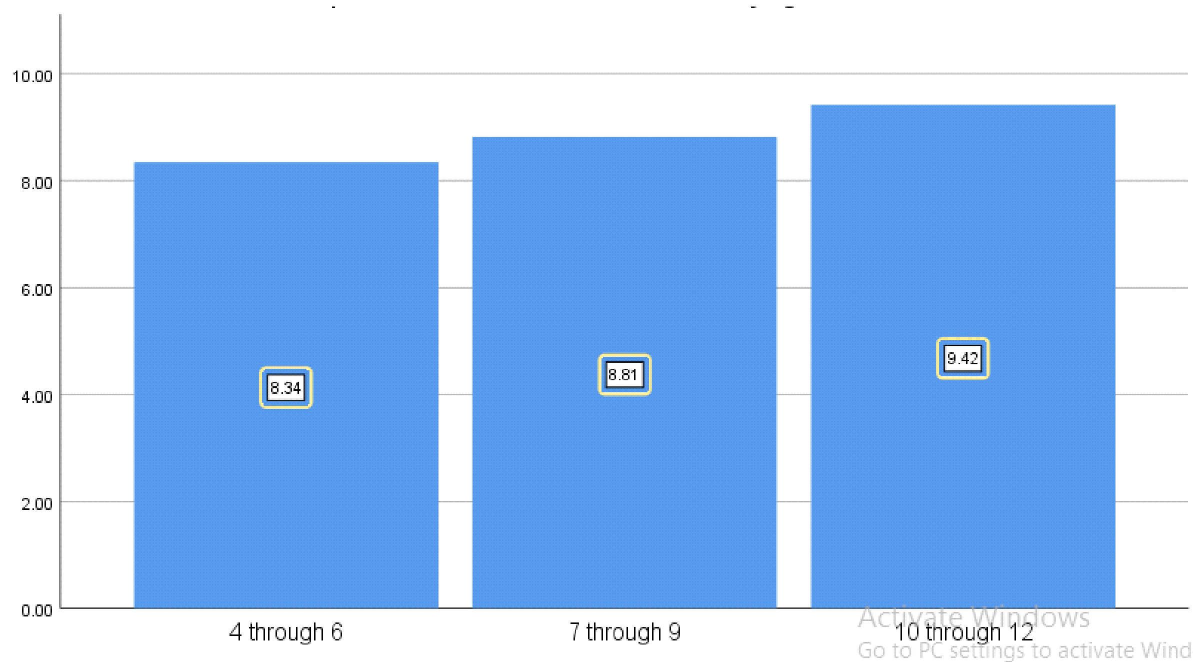
The smallest and largest adenoid size among all study population measured 3.60 and 15.90 respectively. There was no significant difference in mean adenoid size between each group ($p > 0.05$, Table 3 and Figure 4)

Age group	Number of patients	Mean adenoid size (A)	Minimum	Maximum	Standard deviation

I	**38**	**8.3368**	**3.60**	**12.80**	**2.43293**
II	**38**	**8.8132**	**4.00**	**15.90**	**2.7219**
III	**38**	**9.4197**	**5.30**	**14.90**	**2.60694**

Table 4. Mean adenoid size among different age groups
(Sept 25, 2019, Addis Ababa University, Addis Ababa, Ethiopia)

Figure4. Simple bar showing the mean adenoid size among different age groups
(Sept 25, 2019, Addis Ababa University, Addis Ababa, Ethiopia)

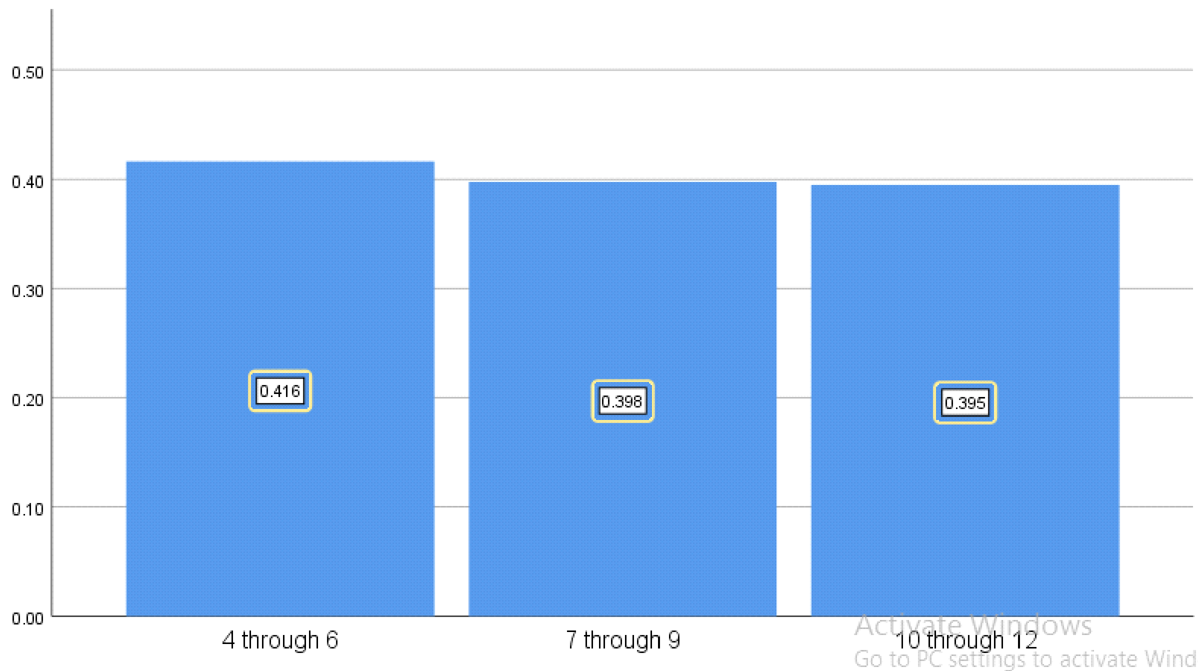


Similarly the mean nasopharyngeal space depth showed an increase as we go from group one to group three age groups but there was a significant difference in all comparisons between each groups (P <0.05)

Age group	**Number of patients**	**Mean nasopharyngeal depth (N)**	**Minimum**	**Maximum**	**Standard deviation**
I	**38**	**20.0368**	**10.80**	**25.80**	**2.88897**
II	**38**	**22.0789**	**13.70**	**29.60**	**3.27943**
III	**38**	**23.8316**	**19.10**	**29.80**	**2.76133**

Table 5. Mean nasopharyngeal space depth among different age groups (Sept 25, 2019, Addis Ababa University, Addis Ababa, Ethiopia)

Figure 5. Simple bar showing the mean adenoid to nasopharyngeal space ratio among different age groups (Sept 25, 2019, Addis Ababa University, Addis Ababa, Ethiopia)



The adenoid to nasopharyngeal ratio also did not show a significant difference between each group similar to the adenoid size ($p > 0.05$)

Age group	Number of patients	Mean adenoid to nasopharyngeal ratio (ANR)	Minimum	Maximum	Standard deviation
I	38	.4161	.19	.66	.10777
II	38	.3978	.20	.58	.09800
III	38	.395	.21	.58	.09589

Table 6. Mean adenoid to nasopharyngeal space ratio among different age group

(Sept 25, 2019, Addis Ababa University, Addis Ababa, Ethiopia)

Chapter Five

5.1. Discussion

Adenotonsillar hypertrophy has been diagnosed by more qualitative methods but adenoid to nasopharyngeal ratio, originally described by Fujioka et al (5) and Linder-Aronson (14), was advocated as a determinant of the degree of nasopharyngeal obstruction by enlarged adenoids by subsequent authors.

There are many variable study results regarding the radiologic parameters for patients with suspected upper airway obstruction secondary to ATH. However it has been reported by many researchers that adenoid to nasopharyngeal ratios evaluated on lateral x-rays showed a significant correlation with endoscopic evaluation (15). Flexible endoscopy, which is considered the gold standard, is not available in resource limited areas like our country Ethiopia. Therefore x-rays remain the most practical imaging modality. However for reasons that are mentioned in the previous chapters, we evaluated the upper airway of children who have undergone CT of the Head &/ Neck for reasons other than upper air way obstruction.

The statistically analyzed mean ANRs in our study were 0.416, 0.397 and 0.395 for Group I, II, and III respectively with the highest value of 0.66 detected in group I. Despite the fact that there was no significant difference between each age groups, those results are consistent with previous x-ray based studies in terms of the highest value detected in group I and subsequent decrease of the ANR across the different age groups as described by Fujioka et al (5) who found that the ANR reached its highest value of 0.59 at the age of 4 years and 6 months after which it gradually decreased to 0.52 at the age of 12 years and 6 months.

On the contrary the mean adenoid size showed a non significant increase as we go from Group I to Group III, measuring 8.32, 8.41, 9.42 mm respectively. This is in contrast to Pruzansky (16) observation that the large adenoids are seen in children aged 4-6 years old which was supported by Fujioka et al. results. Ganghadra et al (7), who used the same age group subjects as in our case, also showed a significant decrease in mean adenoid size as children age goes from group I /II to Group III. The fact that the subjects in our study showed an increase in the mean adenoid size across the three age groups warrants further study as to whether this is unique to Ethiopian children or has other explanation/s.

The nasopharyngeal space depth in our analysis showed significant ($P<0.05$) increase as the age progresses from 4 to 12 years which is consistent with many of previous studies including articles published by Linder-Aronson S. and Woodside DG (6) who reported an increase of nasopharyngeal space depth until the age of 18 years regardless of gender disproving a previous belief thatsays patients with upper airway obstruction have narrow nasopharyngeal space since birth . This was in contrast to the results found by Ganghadra et al (7), who tried to explain it in terms of the effect of enlarged adenoids on the growth of the nasopharyngeal space as the subjects included in his study comprised of patients with signs and symptoms of upper air obstruction. However Yosuf et al (17) also found similar nasopharyngeal space depth with no significant difference as age progresses even in the normal or control groups.

Therefore unlike the mean nasopharyngeal space depth which showed a progressive statistically significant increase, both the mean adenoid size and the ANR in our study did not show significant differences between each groups unlike the x-ray based study done by Ganghadra et al (7) which showed as significant difference of both parameters as the subjects age goes from group I/II to Group III. The statistically not significant decrease in ANR across the age groups in our study can be either because of the consecutive non significant increase in the mean adenoid size or the statistically significant nasopharyngeal depth increase across the age groups seen in our subjects as oppose to those reported by Ganghadra et al (7). However, the mean adenoid size increase particularly from group I and II to group III, may need further study to scientifically explain why.

Articles	Results		
	Age groups (years)	**ANR**	**Values for**
Fujioka et al	**1/12-16**	**> 0.8**	**Adenoidectomy candidates**
Yosuf et al	**4-6 , 6-8 , 8-10**	**0.57 / 0.48 / 0.50**	**Normal subjects**
Elwany et al	**3-7**	**0.58 / 0.71**	**Normal subjects / adenoidectomy candidates**
Gangadhara et al	**4-6 /7-9 / 10-12**	**0.75 / 0.73 / 0.60**	**Normal subjects**
Our study	**4-6 / 7-9 / 10-12**	**0.416 / 0.397 / 0.395**	**Normal subjects**

Table 7. Summary of different studies and values of Adenoid to Nasopharyngeal ratio (7)

Generally when subjectively compared to previous x-ray based results there is an observation that our CT based measurement of the mean adenoid size and ANR are significantly lower than the former reports. We believe the difference in these measurements can be multifactorial but the most important reasons are discussed below.

The first important reason can be the accuracy of lateral x-rays used by previous authors, because the traditional postnasal radiographs has limitations in that the three-dimensional structure of the airway is represented as two-dimensional image. On lateral films alone, the exact soft tissue structures are undetectable because the overlap of numerous structures can lead to great variations in the airway on lateral radiographs (13). In addition it is difficult to evaluate the airway from various angles, such as frontal and sagittal views using reconstruction unlike cross sectional imaging modalities.

Another equally important reason is the different characteristics of the subjects recruited .The sample populations in many of the previous studies consisted of the patients with signs and symptoms of suspected upper air way obstruction. In our study there were clinical indications for the CT exams done therefore those patients were not a random sample of the normal population. But unlike that of Fujioka et al and other investigators, the patients included in our study were screened for upper air way obstruction based clinical score originally developed for Obstructive Sleep Apnea (OSA).

The different techniques of radiologic measurements used by different researchers can also have a role for the discrepancy. For example unlike the Fujioka's method Yosuf et al (17), who also conducted a study on 150 children aged 4-10 years old, used two bony references including the posterosuperior sphenobasioccipital synchondrosis and basin and the nearest point of adenoid tissue to the posterior nasal spine. He separately measured the nasopharyngeal depth and adenoid thickness three times based on the three landmarks and the mean of the three ANRs was considered to be the normal mean of the subjects. For the reason of ease of localization the landmarks used by Ganghadra et al (7) also used the same method as Yosuf et al (17). However, despite the difference in measuring the parameters those studies demonstrated that ANR can be a reliable criterion for evaluating adenoidal hypertrophy rather than the size of the adenoid size alone.

Other less studied explanations but that can potentially affect the results includes the shape of the airway, which was not considered in our study. Not only are the sizes of the adenoids and the nasopharyngeal space but also the shape of the nasopharyngeal space among the major factors that determine the patency of the airway (5). Ohio et al (13) found that children can have different airway shapes and accordingly have difference in the measurement of the adenoid and nasopharyngeal airway.

5.3 Limitations:

There were anatomic variations as a result of rotations for which reason we used 3D reconstruction to reduce the effect on the linear radiological measurements.

Our study was a cross sectional study i.e. no growth follow-up of upper air way structures was done.

5.2 Conclusion

Accurate and objective radiographic measurement of adenoid size and nasopharyngeal airway in pediatrics is very important in making a clinical decision of patients with suspected upper airway obstruction. Although several methods have been described adenoid to nasopharyngeal ration is the mostly used ratio and subsequent authors have mentioned that is a more reliable way of evaluating the patency of the nasopharyngeal air way.

Although many authors have used lateral x rays as a tool for assessing the adenoid size and nasopharyngeal air way we have used conventional CT for ethical purpose in our study. However we believe CT provided us with the most accurate linear measurements of the adenoid and nasopharyngeal airway by avoiding the over or underestimation of the measurements caused by superimposition of soft tissues in 2D images such as lateral x rays.

According to our study we found that the ANR was the most consistent radiologic parameter for evaluating the pediatric upper airway as compared to previous articles. Both the adenoid size did not show a decrease in size as the age progress from 4 years to 12 years which was in contrary to previous report by Ganghadra et although the latter was done on lateral x rays. Moreover the values reported in our study are observed to be significantly lower than the previously reported lateral x ray results of adenoid size and ANR by many scholars. This can be because of multiple factors including the difference of subjects recruited, different evaluation methods and different imaging modalities.

- We recommended radiologists and responsible physicians should use lateral x-rays cautiously while assessing the degree of nasopharyngeal obstruction by enlarged adenoids.
- We also strongly recommend the use of the adenoid to nasopharyngeal ratio rather than using only the adenoid size or the nasopharyngeal space measurement.

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Appendix

Questionnaire

Study Title: Assessment of pediatric adenoid size and adenoid to nasopharyngeal ratio (ANR) on conventional CT, TikurAnbessa Specialized Hospital (TASH), Addis Ababa, 2018/19

Age: …… **Sex: ……**

Questions: Please mark or encircle the proper answer for the following multiple choice questions.

1. Does the patient have history of adenoidectomy or adenotonsillectomy?

   A. Yes
   B. No

(NB: If the answer to the above question is yes, Please skip the rest of the following questions in the questionnaire.)

2. Does the patient have any history of difficulty of breathing?

   A. Never
   B. Occasionally
   C. Frequently
   D. Always

3. Does the patient have recent history of snoring?

   A. Never
   B. Occasionally
   C. Frequently

D. Always

4. Is there any recent history of sleep apnea?

A. Yes
B. No

ConsentCertificate Form

I the investigator, have explained the purpose of the study and hereby I submit that privacy of all data collected will be maintained at all times

Signature………….

I have been explained to and understand the purpose of the study and voluntarily accept to participate.

Signature…………….