

# Predictability of Sex from Frontal Sinus in Nepalese Population

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## ABSTRACT

### Background

Various methods had been used for personal identification. Scientific basis of identification was initiated and progressed after 19<sup>th</sup> century which may be attributed to various scientists. With the invention of X-ray the field of identification further progressed. Modern radiological diagnostic equipments have greatly assisted in the field of forensic. Frontal sinuses are paired lobulated air cavities located posterior to superciliary arches in the frontal bone. Computed Tomography is best used to study frontal sinuses.

### Objective

To evaluate bilateral Frontal sinus for sexual dimorphism using Computed Tomography.

### Method

Anterior posterior length, transverse width and height of the bilateral Frontal sinus were directly measured on CT DICOM image, using Electronic Caliper in DICOM viewer software. A total 100 CT scans, 50 of each sex were collected was analysed using SPSS-20 in present study.

### Result

The mean age distribution for male is 34.74±8.66, and for females 35.34±8.88. The mean of all the measurements take was larger in males in comparison to females with  $p < 0.00$ . The paired t test showed left side is larger than right. The discriminant function showed high significance for each measurement and also when all the measurements were combined.

### Conclusion

Though the study being unique for Nepalese population, caution should be taken when frontal sinus is used as the only parameter. However in combination with other morphometric data is advised.

## KEY WORDS

*Computed tomography, Frontal sinus, Identification, Lobulated air cavities, Sexual dimorphism, Superciliary arches*

## INTRODUCTION

Historically, various methods had been used for personal identification, relying on one's memory in order to identify based on appearance and voice was the most common methodology applied. After 19<sup>th</sup> century scientific based forensic identification was initiated and progressed. Today's advancement in the field of identification can be attributed to many scientists, Johannes Evangelist Purkinje for documentation of finger print followed by Sir Francis Galton who later classified finger print, which is used till date for identification. Similarly Alphonse Bertillon gave the 1<sup>st</sup> scientific method for identifying criminals based on measurement of anthropological features. In 1895 the discovery of Rontgen rays by Wilhelm Conrad Rontgen became the foundation stone for the rapid development of Medical science and Forensic identification. On the way there were many important discovery, ABO blood grouping, Rhesus blood grouping and then came DNA fingerprinting and DNA profiling, thus making forensic identification a scientific and skillful art.

First recorded use of radiology in forensic was in 1896 by Prof. Arthur Schuster, since then the field of radiology has made tremendous advancement like USG, CT, MRI, and MSCT. Use of these advances in forensic has also increased. The proposal of Schuller from Vienna in 1921, suggesting use of radiological study of Frontal sinus got us interested, thus we aimed this study to study frontal sinus for prediction of sex in the Nepalese population.

Frontal sinus are paired lobulated air cavities located posterior to superciliary arches in the frontal bone, each of this frontal sinus opens into the corresponding middle meatus via the infundibulum.<sup>1,2</sup> Frontal sinuses are not present at the time of birth but develop from second year of life. Radiological it is evident by five years and is completely developed by 20 years.<sup>3,4</sup> Anthropological study has an element of being population specific, have no such study in Nepalese population further encouraged us to initiate this study.

## METHODS

Following the ethical standard set by declaration of Helsinki, we submitted the proposal to Institutional Review committee of Kathmandu University School of Medical Sciences, Dhulikhel, Nepal for approval. On receiving clearance from IRC, we initiated this cross sectional hospital based study in the aforementioned institute. The study constitutes of 100 CT scan images of individual above the age of 20 years, between the periods May 2018 to August 2018. Of the 100 individual included in this study, verbal consent was obtained from the patient/patient party for the data to be collected with assurance that their identity will be protected. In this study we included randomly selected patients, needed CT scan for diagnostic purpose during the course of their treatment.

Volumetric scan was done on 128 slice Simen Somatom Perspective Scanner at 5 mm thickness with 5 mm interval, the reconstruction was done at 1 mm thickness and the study was conducted on multi planner scan of axial, coronal and saggital view. Cases wherein, any trauma/fracture and any pathology involving the frontal sinus, were excluded from our study. Bilateral Frontal sinuses were measured directly on DICOM image using Electronic Caliper in DICOM viewer software. The following measurements were considered for our study.

Anterior posterior length of Frontal sinus (APL): On Axial section, maximum distance between the anterior point and posterior point of Right (RAPL) and Left (LAPL) Frontal sinus.

Transverse width of the Frontal Sinus (TW): On coronal section, maximum distance perpendicular to the medial wall to outermost point of the lateral wall of the Right (RTW) and Left (LTW) Frontal sinus.

Height of the Frontal sinus (H): On sagittal section, maximum distance between the roof of the sinus and the floor of the Right (RH) and Left (LH) Frontal sinus.

The measurements thus obtained were in centimeters, and were used to calculate the Volume of Right (RV) and Left (LV) Frontal sinus using a mathematically formula given below.

$$\text{Volume} = \text{APL} \times \text{TW} \times \text{H} \times 0.52 \dots \dots \dots (1)$$

Microsoft excels of Windows 7, will be used to enter the data collected and calculated in the initial stage later it was fed to SPSS 20 software for statically analysis. Descriptive statistics will be done of age, the data collected and calculated from which mean, median, minimum and maximum will be analyzed. Then paired t-test will be initiated to compare right and left side of frontal sinus and student t-test for sexual dimorphism of frontal sinus, significance was defined at  $\alpha=0.05$ . Discriminant Function analysis will be subjected to result of student t-test.

## RESULTS

The study aiming to observe sexual dimorphism in Nepalese population was conducted by the Department of Forensic Medicine in collaboration with Department of Radiology in Kathmandu University School of Medical Sciences, constitute of total of 100 3D CT head images belonging to 50 male and 50 female. For males the age distribution ranges from 22 years to 48 years with mean  $34.74 \pm 8.66$  and for female ranges from 22 years to 49 years with mean  $35.34 \pm 8.88$  detailed in table 1.

**Table 1. Age distribution of the sample**

Gender	N	Minimum	Maximum	Mean	Std. Deviation
Males	50	22	48	34.74	8.366
Females	50	22	49	35.34	8.888

**Table 2. Descriptive statistics of the Frontal sinus according to sex**

Sex	Statistics	RH	RAPL	RTW	RV	LH	LAPL	LTW	LV
<b>Male</b>									
	Mean ± SD	1.68±0.66	0.98±0.28	1.90±0.67	1.86±1.41	1.81±0.83	1.04±0.23	2.11±0.82	2.44±2.11
	Median	1.65	1.00	1.98	1.84	1.79	1.01	2.17	1.75
	Minimum	0.70	0.40	0.35	0.06	0.43	0.61	0.64	0.23
	Maximum	3.55	1.93	3.49	7.28	3.64	1.73	4.09	10.06
	Std. Error	0.098	0.041	0.099	0.207	0.121	0.033	0.119	0.308
<b>Female</b>									
	Mean ± SD	1.20±0.58	0.76±0.18	1.20±0.58	0.79±0.96	1.23±0.48	0.79±0.29	1.66±0.57	1.02±0.83
	Median	1.09	0.75	1.09	0.52	1.19	0.74	1.76	0.93
	Minimum	0.37	0.37	0.37	0.05	0.49	0.43	0.45	0.07
	Maximum	3.20	1.16	3.20	5.17	2.34	1.92	2.87	3.25
	Std. Error	0.086	0.027	0.086	0.143	0.070	0.042	0.084	0.123
<b>t test value</b>		3.644	4.293	5.373	4.198	4.134	4.414	3.105	4.255
<b>Std. Error Difference</b>		0.130	0.050	0.131	0.253	0.141	0.054	0.146	0.334
<b>p-value</b>		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

SD: Standard Deviation

The data thus collected showed that of the 100 study samples, 6 cases showed bilateral absence of frontal sinus of which 3 belonged to male and 3 to female. Unilateral absence of frontal sinus was noted in 4 cases of which 3 belonged to female (Right 2; Left 1), 1 to male (Right). The data was analyzed using Descriptive analysis, detailed in table 2, stating males have larger frontal sinus in comparison to female and also that the left side of frontal sinus were larger than the right. In males the mean value for height of frontal sinus were 1.68±0.66 and 1.81±0.83, for Anterior posterior length were 0.98±0.28 and 1.04±0.23, for Transverse width were 1.90±0.67 and 2.11±0.82 and for volume calculated were 1.86±1.41 and 2.44±2.11 of right the left respectively. In females mean for height were 1.20±0.58 and 1.23±0.48, for Anterior posterior length were 0.76±0.18 and 0.79±0.29, for Transverse width were 1.20±0.58 and 1.66±0.57 and for volume calculated were 0.79±96 and 1.02±0.83 for right and left respectively.

The observation made from the descriptive analysis suggested that the data be subjected to student t test and paired t test. Student t test showed high significant (p < 0.000) difference between male and female but the paired t test showed no significant difference between right and left side except for right and left transverse width in females, expressed in table 2 and table 3.

Student t test showing a high significance (p < 0.000) difference, the data collected and volume calculated was further analysed using discriminant function analysis. Since the paired t test showed no significance difference, the right and left side were in combination entered in SPSS for discriminant function analysis to contemplate weather a single dimension measured of frontal sinus irrespective of side has a effect of significance and predictability.

**Table 3. Paired t test to compare Right and Left Frontal sinus in males and females**

Gender	Pairs	Mean	Std. Deviation	t test	p value
<b>Male</b>					
	RH-LV	-0.140	0.766	-1.238	0.222
	RAPL-LAPL	-0.061	0.259	-1.614	0.113
	RTW-LTW	-0.205	0.953	-1.464	0.150
	RV-LV	-0.602	2.021	-2.020	0.049
<b>Female</b>					
	RH-LH	-0.031	0.487	-0.433	0.667
	RAPL-LAPL	-0.041	0.242	-1.137	0.262
	RTWLTW	-0.446	0.641	-4.615	0.000
	RV-LV	-0.231	0.930	-1.651	0.106

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Student t test showing a high significance ( $p < 0.000$ ) difference, the data collected and volume calculated was further analysed using discriminant function analysis. Since the paired t test showed no significance difference, the right and left side were in combination entered in SPSS for discriminant function analysis to contemplate whether a single dimension measured of frontal sinus irrespective of side has a effect of significance and predictability.

Discriminant function analysis for each of the dimension measured showed very promising result with high significance. Eigen value for height was 0.211, for Anterior Posterior Length was 0.270, for transverse width was 0.346 and for volume calculated was 0.273. Canonical Correlation for height was 0.418, for Anterior Posterior Length was 0.461, for Transverse Width was 0.507, and for volume calculated was 0.463. Wilk's Lambda and Chi-square for height was 0.826 and 16.667, for Anterior Posterior Length was 0.787 and 20.795, for Transverse Width was 0.743 and 25.824, and for volume calculated was 0.786 and 20.973 respectively. All the measurements showed very high significance has p value 0.000, depicted in table 4.

All the measurements taken from frontal sinus and the volume calculated, stepwise discriminant function analysis

**Table 4. Discriminant Function Analysis of Frontal Sinus Measurements.**

Gender	RH & LH	RAPL & LAPL	RTW& LTW	RV& LV
Eigen value	0.211	0.270	0.346	0.273
Canonical correlation	0.418	0.461	0.507	0.463
Wilks Lambda	0.826	0.787	0.743	0.786
Chi-square	16.667	20.795	25.824	20.973
Significance	0.000	0.000	0.000	0.000
Structure matrix	R=0.915 L=0.820	R=0.870 L=0.865	R=0.952 L=0.548	R=0.842 L=0.838
Unstandardized coefficient	R=0.755 L=0.973 C=-2.593	R=2.420 L=2.163 C=-4.122	R=1.381 L=0.446 C=-3.011	R=0.488 L=0.366 C=-1.302
Group Centroid	Male=0.444 Female=-0.465	Male=0.503 Female=-0.525	Male=0.569 Female=-0.594	Male=0.505 Female=-0.528

R: Right, L: Left, C: Constant

was developed (table 5). The stepwise discriminant function analysis also showed high significance ( $p < 0.000$ ) with Eigen value 0.540, canonical correlation 0.592, Wilk's Lambda 0.649 and chi-square 36.270.

Eighty percent of the original group was correctly classified between male and female when all the variables of frontal sinus and volume calculated were used. When single variable was used, Height showed 65.6%, APL showed 73.3%, TD showed 76.7% and the volume showed 70.0% predictability.

**Table 5. Stepwise Discriminant Function Analysis of Right & Left Frontal Sinuses.**

Df	Eigen value	Canonical correlation	Wilks Lambda	Chi-square	Sig	Structure matrix	Unstandardized coefficient	Group Centroid
8	0.540	0.592	0.649	36.270	0.000	RH=0.513 RTW=0.761 RAPL=0.615 RV=0.595 LH=0.572 LTW=0.438 LAPL=0.612 LV=0.598	RH=-0.220 RTD=1.840 RAPL=0.522 RV=-0.492 LH=0.448 LTD=-0.334 LAPL=1.649 LV=0.133 C=-4.184	Male=0.711 Female=-0.743

C: Constant

## DISCUSSION

In 1895 Zukerkandl, described the uniqueness of frontal sinus which was confirmed by Christensen.<sup>6</sup> Seventy-four monozygotic and dizygotic twins were examined by Asherson for uniqueness of frontal sinus, stated frontal sinus were unique even in twins.<sup>7</sup> Due to the anatomical location of frontal sinus, it is well preserved in decomposed and/or skeletonized human remains, and remains stable after 20 years of age until old age when pneumatization may occur owing to atrophic changes.<sup>8</sup> The age group of our study

was 20 to 50 years, acknowledging that development of frontal sinus is completed by 20 years of age. Modification in frontal sinus has been documented in tumors, trauma, infection and environmental factors. Applying radiographic image of frontal sinus for identification was suggested by Suhuller, later Culbert and Law described the complete process using pneumatic space. In this study, we studied frontal sinus for sex prediction rather than uniqueness of it.<sup>9-11</sup>

In our study, bilateral absence of frontal sinus was observed in 6% (6% in both sexes), and unilateral absence was seen in 4% of the total sample, of which 6% (4% and 2% in right and left sided respectively) were found in female and 2% in males which was right sided. Absence of frontal sinus was noted in various studies, but percentages differ, 33% bilateral and 12.6% unilateral absence of frontal sinus was noted in Chinese Han population.<sup>12</sup> The Turkish population stated 3.8% bilateral and 0.8% unilateral absence, similarly 10% bilateral and 2% unilateral absence was observed Northern Ireland population.<sup>13,14</sup> Presence of metopic suture is always associated with absence of frontal sinus, was emphasized by Schuller.<sup>15</sup> The difference in absence of frontal sinus both bilateral and unilateral may be attributed to the definition of absence of frontal sinus given by Szilvassy or that there exist a differences on the grounds of environmental as well as genetic factor.<sup>16</sup> Morphology of frontal sinus is affected by growth hormone (somatotropin).

The point where most of the studies on frontal sinus consistently converge, including our study, is that males have larger frontal sinus as compared to that of female.<sup>3,4,6-9,12,14-16</sup> The difference may be attributed to the genetic, hormonal factor and gonadal steroids which affect the response of growth hormone.<sup>17</sup> Our study show that left side of frontal sinus were slightly larger than the right side but studies by Belaldavar et al., Camargo et al. and Ponde et al. showed larger right side of frontal sinus.<sup>18-20</sup> Due to independent development of frontal sinus, the difference was observed, where in it is commonly witnessed that one frontal sinus is larger than the other and sometime it may overlap after crossing the midline, which may be due to unequal resorption of the dipole during sinus development.<sup>13,21</sup>

Student t test showed a significant ( $p < 0.000$ ) difference between male and female in all the measurements and volume calculated were taken in our study. The paired t test showed no significant difference between right and left side of frontal sinus in both the sexes. The predictability was as high as 80% when all the measurements of frontal sinus and volume calculated was used. However when individual parameters of frontal sinus, were taken height of frontal sinus showed 65.6% predictability, Volume calculated showed 70%, Anterior posterior length 73.3% and Transverse width showed 76.7% predictability.

In a study conducted by Camargo et al in Brazilian population demonstrated 79.7% accuracy to predict sex with left area better suited for sex determination.<sup>19</sup> Uthman et al. in a study conducted in Iraqi population demonstrated an accuracy of 76.9%.<sup>22</sup> Our study demonstrated 80% accuracy when all the measurements of right and left side of frontal sinus were combined. In respect to the modalities our study, is similar to that of Uthman et al. they also conducted their study on CT.<sup>22</sup> A much recent study conducted on Indian population by Belaldavar et al. had the accuracy of 65.5%, though our predictability were highest, the difference may be attributed to population, genetics and the environment.<sup>18</sup>

## CONCLUSION

Frontal sinus in forensic for its uniqueness has been the focus of various authors, our study instead focused on sex prediction and the results (80% accuracy) in Nepalese population is promising. However much studies needs to reckon with larger sample from different population in Nepal to determine the accuracy. Using only frontal sinus for sex determination should be cautioned, however in combination with other morphometric may be advised.

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