The golden ratio of nasal width to nasal bone length

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Summary

Purpose: To calculate the ratio of fetal nasal width over nasal bone length at 14-39 weeks' gestation in Caucasian women. *Methods:* Fetal nasal bone length and nasal width at 14-39 weeks' gestation were measured in 532 normal fetuses. The mean and standard deviations of fetal nasal bone length, nasal width and their ratio to one another were calculated in normal fetuses according to the gestational age to establish normal values. *Results:* A positive and linear correlation was detected between the nasal bone length and the gestational week, as between the nasal width and the gestational week. No linear growth pattern was found between the gestational week and the ratio of nasal width to nasal bone length, nearly equal to phi, throughout gestation. *Conclusion:* The ratio of nasal width to nasal bone length, approximately equal to phi, can be calculated at 14-38 weeks' gestation. This might be useful in evaluating fetal abnormalities.

Key words: Nasal bone length; Nasal width; Ratio of nasal width to nasal bone length; Phi; Golden ratio.

Introduction

Throughout history, the ratio for length to width of rectangles of 1.618033 9887498 9484820, also known as the golden ratio, has been considered the most appealing to the eye. In the world of mathematics, the numeric value is called "phi (φ)". Leonardo Da Vinci featured it in many of his such as the Mona Lisa. He explored the human body and calculated the ratios of the lengths of various body parts to one another. Pythagoras, the Greek geometrician, showed that the human body is built with each part in a definite golden proportion to all the other parts [1]. The aesthetic sense is lost and abnormalities start to appear as this proportion is retreated in the human body.

Several alterations of the human genotype provoke modifications in the craniofacial phenotype [2]. Abnormalities seen on a facial profile view may assist in the accurate diagnosis of multiple malformation syndromes such as trisomy 21, trisomy 18 and Apert syndrome [3]. In particular, trisomy 21 is the most frequent autosomal aneuploidy in humans. In such patients, the vertical length and anteroposterior dimensions of the nasal bone were found to be reduced, while the alar base width and the superior and inferior widths of the nostrils were increased [4].

The aim of our study was to calculate and determine the value of the ratio of fetal nasal width over nasal bone length at 14-39 weeks' gestation in Caucasian women and to obtain a rate which would help in the differentiation of normal fetuses from abnormal fetuses.

Revised manuscript accepted for publication February 23, 2010

Materials and Methods

Ultrasonographic measurements of fetal nasal bone length and nasal width of 619 consecutive pregnant women at 14-39 weeks' gestation in a period of two years were obtained as part of routine antenatal examination. Informed consents of each patient were obtained and our cross-sectional study was approved by the ethics committee. Pregnancies with known normal outcomes were included into this study. Patients with fetal chromosomal and structural anomalies, multiple gestations, fetal death, preterm labor, birth weights lower than the 10th percentile or greater that the 90^{th} percentile, and cases in which the face of the fetus could not be visualized due to fetal position or oligohydramniosis were excluded from the study. Therefore a total of 532 patients fulfilling our criteria were included in this study. In patients with regular menstrual periods lasting 28-32 days, the gestational age was determined by the last menstrual period (LMP), confirmed by first or second trimester ultrasound examination. For those who did not know their LMP, measurements of crown-rump length (CRL) in the first trimester, of biparietal diameter (BPD) in the second trimester and the mean gestational age by the average of BPD, head circumference (HC) and femur length (FL) in the third trimester were used to determine gestational age. Fetal measurements were taken by an experienced ultrasonographer, using a curved 5 MHz transducer (Voluson, General Electric, Milwaukee, WI, USA). The nasal bone was measured on the midsaggital view of the fetal face where the chin and lips could be visualized, with a 45° angle of insonation under low brightness adjustment (Figure 1). Each measurement was taken twice and the mean values were calculated. Care was taken to put the cursors on the very top and bottom ends of the fetal nasal bone. The nasal width was measured from the outer margins of the nose at the level of the lower border of the ala nasi, using the modified coronal view which can be obtained by firstly visualizing the plane for measuring the BPD, then moving the transducer anteriorly and rotating it 90° (Figure 2). After identification of the appropriate plane, two independent measurements of the diameter of the nasal width were taken and their average was obtained as the final measurement. Measurements of BPD, HC, abdominal circumference (AC), humerus length (HL) and FL were taken in the standard planes. All measurements were calibrated at 0.1 mm. The ratio of nasal width to nasal bone length was calculated for each case.

Figure 1. — Nasal bone length.

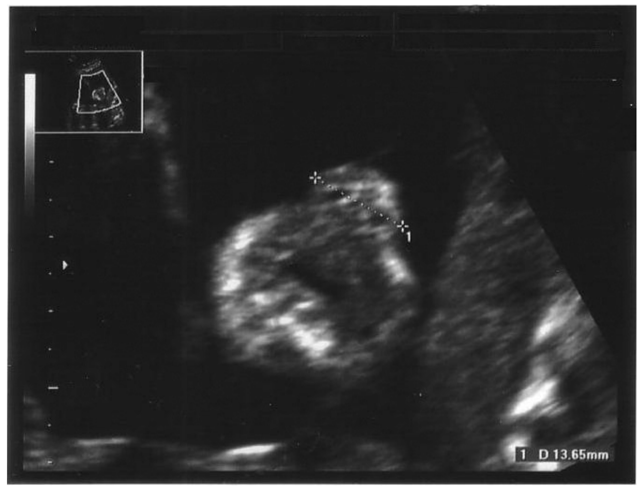

Figure 2. — Nasal width.

Statistics

Statistical analysis was performed with the SPSS 13.0 package program (SPSS Inc., Chicago, IL, USA). Descriptive statistical methods (mean, standard deviation) were used in the evaluation of the study data. Statistical significance was considered achieved at $p < 0.05$. The mean and standard deviation values for nasal width, fetal nasal bone length and their ratio to one another were computed at biweekly intervals. The nasal width diameter and nasal bone length were analyzed as the dependent variables, paired with gestational age as the independent variable. To calculate the intraobserver variability, the intraclass correlation coefficient (intra-CC) with 95% confidence interval (CI 95%) was used.

Results

The study population consisted of Caucasian patients. The ages of the pregnant women ranged from 17 to 44 and the mean age was found to be 30.50 ± 5.92. A total of 13 subgroups were formed according to the gestational week in biweekly intervals. The mean gestational week was calculated to be 22.98 ± 6.01. Each patient delivered after 37 completed weeks. The mean birth weight was 3,268 g (range 2,550-4,270). The mean of the nasal bone length, the nasal width and the ratio of nasal width to nasal bone length were 8.10 ± 2.61; 13.09 ± 4.17 and 1.618 ± 0.07, respectively. We achieved the midsaggital view or coronal view easily if the fetal head was in the transverse or occiput posterior position. We obtained midsagittal and coronal views of the face in a few minutes in 86% and 91% of the cases, respectively. We could not measure the nasal bone length and/or nasal width due to fetal position in 5.8% of target fetuses despite 10-12 min of examination. One set of measurements (nasal bone length and nasal width measurements) was obtained for each patient and the intraobserver variabilities for the nasal bone length (intra-CC: 0.92) and nasal width (intra-CC: 0.93) were considered very good.

A positive and linear correlation between nasal bone length and gestational week was detected with the simple regression analysis. The definitive coefficient of the gestational week on nasal bone development was found to be $r^2 = 0.95$ and this relationship was found to be statistically significant ($p < 0.001$). The regression formula for the relationship between gestational age and nasal bone length was defined as: nasal bone length (mm) = gestational week x 0.42-1.63, ($r^2 = 0.76$; $p < 0.001$). Nasal width measurements throughout gestation are given by the equation: nasal width (mm) = gestational week x 0.68–2.45, ($r^2 = 0.85$; $p < 0.001$). The relationship between biometric parameters reflecting fetal development, the BPD, HL, FL and nasal bone length were evaluated and a positive correlation was found between these parameters. The same relation was also found between the biometric parameters of fetal development and nasal width. Nasal bone development and nasal width also demonstrated a linear growth pattern. Table 1 gives the mean and standard deviations of the nasal width and nasal bone length, and their ratio to one another according to the gestational weeks (Table 1). No linear growth

Table 1. — *The mean values and standard deviations (SD) for nasal widths, nasal bone lengths and their ratio to one another in the normal fetus.*

Gestational weeks		Nasal os length		Nasal width		Ratio (nasal width/ nasal length)	
	Number	Mean	SD	Mean	SD	Mean	SD
14-15	19	3.83	0.34	6.20	0.49	1.623	0.104
16-17	66	5.01	0.48	8.01	0.75	1.602	0.065
18-19	102	6.19	0.58	10.03	0.87	1.624	0.109
20-21	75	7.29	0.45	11.81	0.71	1.620	0.048
22-23	81	8.10	0.58	13.10	0.99	1.618	0.039
24-25	42	9.02	0.74	14.60	1.17	1.620	0.049
26-27	29	9.79	0.73	16.07	1.00	1.644	0.075
28-29	26	10.75	0.59	17.34	1.09	1.612	0.052
30-31	21	11.31	0.43	18.32	0.89	1.621	0.086
32-33	31	11.79	0.65	19.40	0.84	1.648	0.079
34-35	13	12.72	0.54	20.27	1.06	1.596	0.095
36-37	14	13.42	0.58	21.12	0.74	1.576	0.072
38-39	13	14.18	0.60	22.13	0.94	1.562	0.064
Total	532	8.10	2.61	13.09	4.17	**1.618**	0.075

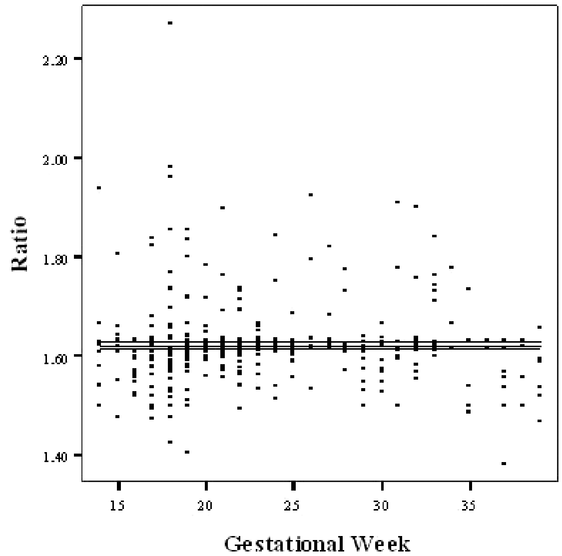

Figure 3. — The ratio of nasal width to nasal bone length.

pattern was found between the gestational week and the ratio of nasal width to nasal bone length, as this ratio remained fairly constant throughout gestation (Figure 3).

Discussion

The nasal bone, actually composed of two bones, can be visualized by ultrasonography after the tenth week of pregnancy [5]. If not visualized at the right plane, it can be over- or under-measured or even be missed totally [6]. The evaluation must be done with the fetus in the neutral position and with an angle close to 45°. During observations of angles less than 45° or higher than 135°, the bones may seem shorter than they actually are or may even be found to be absent [7]. The machine quality, experience of the operator, presence of oligohydramnios, obesity, fetal position, and the gestational week are factors that can affect the successful evaluation of the nasal bone [8]. A strict medial profile is an essential condition for the measurement of nasal bone length, since nasal bones have a trapezoidal shape and inner edge is shorter than the external one [9]. We could not visualize the mid-sagittal view of the face in 9.4% of our targeted fetuses at 14-39 weeks due to fetal position, maternal obesity, maternal hypotension due to supine position, and oligohidramnios, similar to Pilu et al.'s study in which this ratio was 11% [10]. Visualization or the measurement of the nasal bone is a method that can be of help in the early screening of chromosomal anomalies. It has been shown that the absence of the nasal bone in the first trimester, and the absence or hypoplasia of the nasal bone in the second trimester especially, can be associated with chromosomal anomalies. In Cicero *et al.'s* study [11] in which 1,046 patients at 15-22 weeks of gestation were examined, 61.8% of patients with fetal trisomy 21 and 1.2 % of patients with normal fetuses were found to have nasal bone hypoplasia (< 2.5 mm). Has *et al*. [12] found the prevalence of absent nasal bone to be 0.39% in chromosomally normal fetuses, and 33.3% in Down syndrome fetuses. No absent nasal bones were observed in this study. The possibility of a variation in nasal bone lengths among different races has been proposed although there are also studies indicating that there are no differences in the nasal bone lengths among three ethnic races [13, 14]. Nasal bones demonstrate a linear growth pattern in parallel with the other bony structures in the body. In the first ultrasound study performed by Guis et al on this subject [9], a linear increase of 4-12 mm in the nasal bone length between the 11^{th} and 35^{th} weeks of pregnancy was found. Sonek *et al*. [15] found the nasal bone length to be between 1.3 and 14.7 mm at 11-40 weeks of gestation. In our study, the mean nasal bone lengths ranged from 3-15 mm at 14-39 weeks of gestation and the growth pattern was found to be linear as demonstrated in other studies.

The mid-sagittal view of the face may reveal subtle abnormalities including abnormal nose, micrognathia, enlarged tongue, or absent nasal bridge. On the other hand, most facial anomalies detected prenatally involve visualization of the fetal profile, axial scanning through the level of the fetal orbits and frontal view of the upper lip and mouth [16]. Some fetuses with chromosomal abnormalities, especially trisomy 21, may have wide noses with increased binasal diameter. Fetuses with increased nasal width may be at an increased risk for trisomy 21. In Pinette *et al.'s* [17] study in which fetal nasal width nomograms were calculated in 782 normal Caucasian patients, with use of the mean ± 1 SD as a cutoff value, the results showed a sensitivity of 80%; with a specificity of 67% for the diagnosis of trisomy 21. Nonetheless, this cutoff resulted in an unacceptably high false-positive rate (33%). In our study, we formed a similar nomogram of nasal width from measurements obtained from 532 fetuses with normal outcomes; however the patients were grouped according to gestational weeks with two-week intervals instead of one-week intervals. We preferred this way of grouping patients as our study population was not as large as Pinette's and co-workers. Goldstein *et al*. [18] grouped their patients according to their gestational weeks between 22 and 28 weeks of gestation. However, they preferred to group the rest of their patients in two-week intervals, as we did in our study. Goldstein *et al*. calculated the nomogram of the nasal width. The mean nasal widths in our study were in correlation with the 50^{th} percentile values in their study, except for the mean values in the 38^{th}-40^{th} gestational weeks. The difference in the mean nasal width of the groups at 38-40 gestational weeks between the two studies was 3 mm. This is probably due to the difference in the number of patients and the difficulty in obtaining the appropriate plane for measurement. In addition, the percentile values in the 38^{th}-40^{th} gestational week were lower than the percentile value in the 33^{th}-35^{th} gestational week in Goldstein *et al.'s* study. We obtained the coronal view in a few minutes in 91% of the cases. Similarly, Goldstein's group reported obtaining the same view in 95% of their cases. The linear growth relationship between the nasal width and gestational age was observed in our study, as well as the studies of Pinette *et al*. and Goldstein *et al*. [17, 18].

Because fetuses with chromosomal abnormalities typically have wide, flat, saddle-shaped noses, the ratio of nasal width to nasal bone length may be helpful in differentiating the abnormal fetuses with chromosomal abnormalities or genetic syndromes from normal fetuses. In our study, the ratio of nasal width to nasal bone length was approximately equal to phi. Ten fetuses were excluded from the study due to known chromosomal abnormalities detected by amniocentesis and karyotyping. No nasal bone could be detected in one fetus with trisomy 21 and one of the fetuses had a normal nasal bone length in accordance with its gestational week. The nasal bone lengths of the remaining eight patients were shorter than the mean value according to the gestational week. On the other hand, the nasal width was wider than normal in five of the ten fetuses. The ratio of nasal width to nasal bone length was found to be much higher than phi in eight fetuses. One fetus had a rate fairly higher than phi. The rate of another fetus could not be calculated since it had no nasal bone.

Although this study defines normal growth of the fetal nose, abnormal growth was not studied due to the small number of fetuses with chromosomal abnormalities. More abnormal fetuses will have to be studied to determine the usefulness of these data in differentiating the normal and abnormal fetus. Moreover, our population was mainly of Caucasian origin. Further studies are needed to study ethnic variability. A final challenge to the method is the feasibility of obtaining a profile and a modified coronal view of the face. The mid-saggital view is most easily achieved with the fetal head in the transverse or occiput posterior position; similarly the coronal view can be simply obtained with the fetus in the transverse position. Conversely, the back-up position of the head makes achieving the mid-saggital and coronal view difficult and time-consuming. If the fetus is in the back-up position, we can either wait for a few minutes or gently apply external pressure over the fetus to change the fetal position. We did not take precise measurements of the time it took to obtain the nasal width and nasal bone length measurements. Although it does take some time to measure the nasal width, we recon the time spent to calculate this rate is acceptable to introduce it to the obstetric ultrasound examination, especially to the 18-22 week ultrasound.

As a conclusion, during the examination of the face and profile of fetuses during obstetric ultrasonography as part of the surveillance for genetic syndromes, and chromosomal or other abnormalities, the nasal bone length and nasal width can be measured as well. The ratio of nasal width to nasal bone length, which is approximately equal to phi in healthy fetuses, can be calculated at 14-39 weeks' gestation. This calculation might prove useful in evaluating pregnancies at high risk for fetal abnormalities. Further studies with more fetuses with abnormal karyotype are needed to evaluate the effectiveness and sensitivity of the calculated ratio, especially in comparison to the measurement of nasal bone length as a single parameter.

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