Prenatal Growth of the Human Vomeronasal Organ

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ABSTRACT Background: Vomeronasal organs (VNOs) are paired epithelial structures located adjacent to the nasal septum that form in the late first trimester of human fetal development. Although VNOs have long been known to exist in fetal and adult humans, some studies continue to suggest that these structures may be degenerative or functionless. Little is known of the growth of the VNO.

Methods: The present study examined length and volume changes of the human VNO in 26 “normal” (10 female, 16 male) histologically prepared fetuses from the University of Pittsburgh and the University of Michigan across three trimesters (8-30 weeks postmenstrual age). A computer reconstruction technique was used to quantify lengths and volumes of right and left VNOs, and regression equations were generated to assess growth rates.

Results: A linear increase in VNO length and a logarithmic increase in VNO volume with increasing postmenstrual age was found. Volume increase was noted for both the vomeronasal epithelium and the lumen of the VNO. A comparison with most estimates of adult human VNO length suggested that further prenatal or postnatal size increase occurs. The growth curves also suggested a more rapid growth in VNO length and volume for females than for males.


Key words: vomeronasal organ; fetal growth and development; nasal capsule; sexual dimorphism

Vomeronasal organs (VNOs) are paired epithelial structures that are located bilaterally and adjacent to the base of the nasal septum (Fig. 1) in most terrestrial vertebrates (Broom, 1897; Negus, 1958). The VNOs are receptor units for the “accessory olfactory system,” which is comprised of the VNO, vomeronasal nerves, and accessory olfactory bulb, and is anatomically distinct from the main olfactory system (McCotter, 1912). The VNO monitors more specific chemical signals than the olfactory system and may be especially sensitive to species-specific “pheromones” (Wysocki, 1979). Such chemical cues have been shown to be related to reproductive behaviors (Powers and Winans, 1975), functioning as inter- and intrasexual communication (Wysocki and Meredith, 1987; Wysocki and Lepri, 1991). In addition to differences in function, sexual dimorphism in size of structures in the accessory olfactory system has also been reported in vertebrates such as salamanders (Dawley and Crowder, 1995) and rats (Segovia and Guillamón, 1982; 1993).

Recent studies have established frequent presence and possible functional characteristics of the VNO in large samples of adult humans (Moran et al., 1991; Stensaaas et al., 1991; Takami et al., 1993; Monti-Bloch et al., 1994; Berliner et al., 1996), emphasizing that little is known of its prenatal and postnatal growth. The human VNO commences development at about 37 postovulatory days of age as epithelial invaginations bilateral to the nasal septum (Bossy, 1980) and superior to the anterior paraseptal cartilages (PCs) on each side (Read, 1908). These grooves fuse laterally to form

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tubular structures (Kreutzer and Jafek, 1980) that are present across all three trimesters of fetal development (Smith et al., 1996a). Although the VNO has long been known to be present in adult humans (Potiquet, 1891; Mangakis, 1901), age-related retrogression of the human VNO during fetal development has continued to be suggested by many investigators (Humphrey, 1940; Nakashima et al., 1985; Kjaer and Fischer Hansen, 1996). Few studies have addressed the question of prenatal VNO degeneration by quantifying its dimensions across fetal ages. Smith (1995) and Smith et al. (1996a) found that VNO length and volume appeared to increase across human fetal postmenstrual age, although to a lesser extent than seen in other midfacial structures such as the nasal septum and PCs (Siegel et al., 1987; Mooney et al., 1994; Smith, 1995). It is unclear whether the volume increases reflected growth of the vomeronasal epithelium (VNE) or lumen expansion (Smith, 1995).

The present study assesses the timing of human fetal VNO length, overall volume, and VNE volume changes to estimate the amount of prenatal growth across three trimesters of development and to provide a comparison to existing parameters of adult human VNO size. The possibility of sexual dimorphism of VNO size is also investigated.

MATERIALS AND METHODS

The human fetal sample examined included 20 fetuses from the University of Pittsburgh (Siegel et al., 1984, 1987) and 6 fetal specimens from the University of Michigan (Burdì et al., 1986). The specimens were selected in part on previous assessments of grossly “normal” external morphologies (Burdì et al., 1986; Siegel et al., 1987). Although the use of collections of spontaneously aborted formalin-fixed fetuses has been criticized (Hellman et al., 1969), Birkbeck (1976) found fresh fetal material from psychosocial abortions to differ little in somatic measures from those based on the former type (e.g., Streeter, 1920). Mooney (1986) found no differences between anthropometric measures of the University of Pittsburgh sample used in the present study and those from the study by Birkbeck (1976). These findings suggest that the criteria used for selection of “normal” specimens for the present sample were appropriate and that this sample can be used for an accurate study of craniofacial growth.

Fetal material that had been serially sectioned with each section sequentially numbered was also required so that structures could be isolated, reconstructed, and quantified by computer three-dimensional reconstruction (Siegel et al., 1983; Mooney, 1986). The fetal heads had been celloidin embedded, oriented in the coronal plane, and sectioned at 15-30 µm (Siegel et al., 1987; Burdì et al., 1986). Every third to sixth section was mounted on a numbered glass slide and stained with hematoxylin and eosin (Siegel et al., 1987) or trichrome connective tissue stain (Burdì et al., 1986).

Methods of aging fetal material depend on the state of preservation of the specimen, and numerous investigations have demonstrated the accuracy of fetal long bone lengths as an alternative to the use of traditional methods (e.g., crown-heel length; O'Brien et al., 1981; Kelenen et al., 1984; Magriples and Laitman, 1987).
Numerous investigators have also suggested the use of multiple anthropometric measurements for fetal age estimates because of tissue shrinkage or stretching that may occur during handling and fixation (O’Rahilly, 1973; Birkbeck, 1976; Shapiro and Robinson, 1980). Because long bone length measures were unavailable for use in the present investigation, fetal specimens that had been measured in more than one anthropometric parameter were used. For each specimen, sitting height, foot length, and head modulus measurements were plotted against Streeter’s Developmental Growth Curves (Streeter, 1920), and an average of the three estimated fetal ages was then calculated for an overall “best-fit” fetal postmenstrual age (Siegel et al., 1984; Smith et al., 1996a). The entire sample was 8-30 weeks postmenstrual age and was composed of 10 female and 16 male individuals (Smith et al., 1996b).

The midfacial region of each specimen was examined grossly by using a Wild stereomicroscope and an Olympus BX-50 stereomicroscope at magnifications of ×6-600. Presence or absence of the VNO was noted in all specimens, and the number of sections in which the VNO was present was counted for length calculation based on the recorded sectional thicknesses. VNOs were identified by the positional relationships to the septal and paraseptal cartilages and by the presence of a lumen surrounded by pseudostratified columnar epithelium (Smith et al., 1996a). University of Michigan specimens were photographed with tungsten color slide film, and a metric scale was photographed for each magnification (Smith, 1995; Smith et al., 1996a). The correlation between measurements of structures digitized directly from microscopic slides and those from photographic slides has been shown to be high, indicating the validity of this technique (Smith et al., 1996a).

For computer three-dimensional reconstruction (Siegel and Todhunter, 1979; Siegel et al., 1983), structural aspects of VNOs were digitized directly from the microscopic or photographic slides with an Olympus stereo zoom microscope with a Panasonic WV-CD 130 camera attachment. Images were projected onto a SONY color monitor, and the outer perimeter (at the level of the basement membrane) and inner perimeter (at the apical aspect of the VNE) of VNOs were manually

Fig. 2. The vomeronasal organs (VNO) were present in all fetuses and were located adjacent to the base of the nasal septum (NS). VNOs consisted of the tubular vomeronasal epithelium (VNE), with a central opening or lumen (LUM). Note the relatively smaller lumen in the 8- (a, ×125) and 10- (b, ×125) week specimens compared with the relatively larger lumen seen in the 18- (c, ×125) and 24.5- (d, ×60) week specimens. The 24.5-week specimen (d) illustrates the vomeronasal groove (open arrow), which represents the communication of the VNO with the nasal cavity. Bars = 250 µm.
digitized in each section in which the organs were present after the cross-sectional "vomeronasal groove" (Fig. 2). Thus, an extracted image of both the entire VNO and the VNO lumen was obtained for each section. Additional structures were digitized to facilitate alignment, such as the inferior tip of the nasal septum and PCs (Fig. 1). After all relevant sections were digitized, each boundary file contained the digitized coordinates of VNO perimeters and structures for alignment. A program was used to rotate and/or translate adjacent boundary files until serial section alignment was visually verified (Siegel et al., 1987). These cross-sectional images were combined, and intermediate sectional boundaries (from unused sections) were interpolated to produce a three-dimensional reconstruction. The sum of the areas of the digitized VNO boundaries and those of intervening interpolated sections were used to compute volumes. VNE volume was obtained by subtracting lumen volume from the overall VNO volume. The three-dimensional reconstruction technique used in the present study was designed to recover data lost through sampling of sections, and the interpolation carried out by this program accounted for missing (unused or damaged) intermediate sections (Todhunter et al., 1983). However, specimens with epithelial damage at the most anterior or posterior ends of the VNO were excluded from analysis. All computer-generated reconstructions and quantitative data were produced and stored on a Gateway 2000 486DX2/50 computer and Tecmar Qt-60e tape drive (Siegel et al., 1987).

Lengths and volumes were plotted against fetal postmenstrual ages to produce growth curves. These plots were generated and assessed by using Tablecurve 2.10 software (Jandel Scientific) to identify the best regression equation for each structure. In all cases, the "simplest" regression equation that adequately described the sample variation was selected. These growth curves were utilized to assess intersex differences in growth rates by using Sokal and Rohlf’s (1981) t-s test for the Homogeneity of Regression Line Slopes.

RESULTS

The VNOs were present bilateral to the cartilaginous nasal septum in all fetuses (Fig. 2). The left VNO of one 21-week specimen could not be located due to tissue damage, but the vomeronasal groove was present anterior to damaged sections. In most specimens, an internal opening (lumen) of the VNO was preserved and usually conformed in shape to the cross-sectional perimeter (basal epithelial border) of the organ (Figs. 2 & 3). The VNOs of specimens between 8 and 15 weeks postmenstrual age were characterized by small lumens relative to epithelial thickness. Most older specimens exhibited a more expansive lumen, making the epithelium appear to be relatively thinner (Fig. 2). Three-dimensional computer reconstructions supported these observations (Fig. 3), illustrating that lumen volume accounted for a greater proportion of overall VNO volume in older specimens.

Quantification of VNO length was possible for 22 right and 22 left VNOs (Table 1). Four right and four left specimens had epithelial damage in regions immediately anterior or posterior to sections containing the VNO, making length calculation impossible. These specimens and one specimen with intermediate VNO damage were therefore also excluded from volumetric reconstruction. The apical surface of the VNE in eight VNOs was damaged, and for these specimens the VNE volume could not be calculated.
Individual (i.e., right or left) VNO lengths were 228-3,015 µm (a 1,222% increase from smallest to largest lengths).1 Individual overall VNO volumes (including epithelium and lumen) were 2.40-93.05 cc x 10^-6 (3,745% increase). Individual VNO lumen volumes were 0.06-38.56 cc x 10^-6 (6,416% increase) and individual VNE volumes were 2.04-64.88 cc x 10^-6 (3,080% increase).

VNO length increase was adequately described by linear regression equations for both right or left VNOs (R^2 = 0.60 and 0.65, respectively; Table 1; Fig. 4). Overall VNO volume increase was best described by a logarithmic regression equation for right and left VNOs (R^2 = 0.63 and 0.69, respectively; Table 1). Growth curves suggested that most overall VNO volume increase occurred between 16 and 30 weeks of age (Fig. 4). Volumetric measures of both VNO lumen and the VNE were described best by logarithmic regression equations (R^2 = 0.63 and 0.79, respectively, for right and left lumen volume, and 0.69 and 0.75, respectively, for right and left VNE volumes; Table 1). The regression lines for VNE volumes also suggested that an increase occurred between 16 and 30 weeks (Fig. 4). VNO lumen growth curves indicated a relatively later and less rapid volume increase that occurred between 20 and 30 weeks of age (Fig. 4).

In comparisons between sexes, individual VNO lengths were 228-3,015 µm for females (1,222% increase) and 275-2,550 µm for males (827% increase). Individual overall VNO volumes were 2.82-93.05 cc x 10^-6 (3,199% increase) in females and 1.01-55.95 cc x 10^-6 (5,439% increase) in males. Individual VNO lumen volumes were 0.27-38.56 cc x 10^-6 (14,181% increase) in females and 0.06-17.45 cc x 10^-6 (28,983% increase) in males. Individual VNE volumes were 2.54-64.88 cc x 10^-6 (3,080% increase) in females and 2.04-38.5 cc x 10^-6 (1,787% increase) in males.

For all computed lengths and volumes, females exhibited higher R^2 values than males (Table 2). Regression lines of VNO lengths and VNO and VNE volumes

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**TABLE 1. Regression equations of VNO lengths (µm) and volumes (cc x 10^-6) and VNE and lumen volumes (cc x 10^-6) against postmenstrual age for the fetal sample.**

<table>
<thead>
<tr>
<th>Measure</th>
<th>Regression equation</th>
<th>R^2</th>
<th>S.E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>RVNO length (N = 22)</td>
<td>Y = -382.93 + (87.51 x PMA)</td>
<td>0.60</td>
<td>15.85</td>
</tr>
<tr>
<td>LVNO length (N = 22)</td>
<td>Y = -310.15 + (86.25 x PMA)</td>
<td>0.65</td>
<td>14.30</td>
</tr>
<tr>
<td>RVNO volume (N = 22)</td>
<td>Log Y = -6.11 + (0.06 x PMA)</td>
<td>0.63</td>
<td>0.011</td>
</tr>
<tr>
<td>LVNO volume (N = 22)</td>
<td>Log Y = -6.20 + (0.07 x PMA)</td>
<td>0.69</td>
<td>0.010</td>
</tr>
<tr>
<td>RVNE volume (N = 17)</td>
<td>Log Y = -6.04 + (0.06 x PMA)</td>
<td>0.69</td>
<td>0.010</td>
</tr>
<tr>
<td>LVNE volume (N = 18)</td>
<td>Log Y = -6.07 + (0.06 x PMA)</td>
<td>0.75</td>
<td>0.010</td>
</tr>
<tr>
<td>RLum volume (N = 17)</td>
<td>Log Y = -7.4 + (0.09 x PMA)</td>
<td>0.63</td>
<td>0.020</td>
</tr>
<tr>
<td>LLum volume (N = 18)</td>
<td>Log Y = -7.56 + (0.03 x PMA)</td>
<td>0.79</td>
<td>0.012</td>
</tr>
</tbody>
</table>

1N, sample size; RVNO, right vomeronasal organ; LVNO, left vomeronasal organ; RVNE, right vomeronasal epithelium; LVNE, left vomeronasal epithelium; RLum, right vomeronasal organ lumen; LLum, left vomeronasal organ lumen.

2Linear regression equations are based on the regression equation Y = a + (b x PMA); PMA, postmenstrual age (in weeks).

3S.E., standard error of the slope.

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1Data on right and left VNO lengths have been published for comparing the specimens used in the present study with a sample of fetuses with cleft lip and palate (Smith et al., 1996a); VNO volumes were recalculated for the present analysis; intersex comparisons and VNE data have not been published.

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Fig. 4. Individual specimen distribution and regression lines for right and left vomeronasal organ (VNO) lengths and volumes and right and left vomeronasal epithelium (VNE; solid regression line) and lumen (LUM; dashed regression line) volumes for the entire fetal sample. A linear length increase and logarithmic volume increase best describes the VNO; volume increase occurred primarily between 16 and 30 weeks postmenstrual age. Overall VNO volume increase is comprised of increases in both the epithelium and lumen volumes.
exhibited steeper slopes in females than in males (Table 2; Fig. 5). In addition, females exhibited length and volume measures that fell within or above the 95% confidence interval for the entire sample, whereas most males had measures that fell within or below the 95% confidence interval (Fig. 6). However, $t_s$ tests between males had measures that fell within or below the 95% confidence interval for the entire sample, whereas most volume measures that fell within or above the 95% confidence interval for the entire sample.


differences between females and males for VNO length and volume and comparisons between females and males of the fetal sample

<table>
<thead>
<tr>
<th>Measure</th>
<th>Regression equation</th>
<th>$R^2$</th>
<th>S.E.</th>
<th>$t$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>RVNO length</td>
<td>Females (N = 7) $Y = -796.14 + (124.77 \times PMA)$</td>
<td>0.91</td>
<td>17.18</td>
<td>2.42†</td>
</tr>
<tr>
<td></td>
<td>Males (N = 15) $Y = -37.13 + (57.82 \times PMA)$</td>
<td>0.64</td>
<td>17.40</td>
<td></td>
</tr>
<tr>
<td>LVNO length</td>
<td>Females (N = 8) $Y = -734.83 + (119.67 \times PMA)$</td>
<td>0.89</td>
<td>16.93</td>
<td>2.61†</td>
</tr>
<tr>
<td></td>
<td>Males (N = 14) $Y = 69.8 + (54.86 \times PMA)$</td>
<td>0.59</td>
<td>16.39</td>
<td></td>
</tr>
<tr>
<td>RVNO volume</td>
<td>Females (N = 7) $\log Y = -5.94 + (0.070 \times PMA)$</td>
<td>0.87</td>
<td>0.12</td>
<td>0.402†</td>
</tr>
<tr>
<td></td>
<td>Males (N = 14) $\log Y = -6.02 + (0.052 \times PMA)$</td>
<td>0.51</td>
<td>0.14</td>
<td></td>
</tr>
<tr>
<td>LVNO volume</td>
<td>Females (N = 8) $\log Y = -6.15 + (0.074 \times PMA)$</td>
<td>0.95</td>
<td>0.10</td>
<td>0.465†</td>
</tr>
<tr>
<td></td>
<td>Males (N = 14) $\log Y = -6.12 + (0.059 \times PMA)$</td>
<td>0.55</td>
<td>0.16</td>
<td></td>
</tr>
<tr>
<td>RVNE volume</td>
<td>Females (N = 7) $\log Y = -5.98 + (0.064 \times PMA)$</td>
<td>0.86</td>
<td>0.11</td>
<td>0.363†</td>
</tr>
<tr>
<td></td>
<td>Males (N = 10) $\log Y = -5.98 + (0.049 \times PMA)$</td>
<td>0.64</td>
<td>0.13</td>
<td></td>
</tr>
<tr>
<td>LVNE volume</td>
<td>Females (N = 8) $\log Y = -6.11 + (0.067 \times PMA)$</td>
<td>0.95</td>
<td>0.07</td>
<td>0.387†</td>
</tr>
<tr>
<td></td>
<td>Males (N = 10) $\log Y = -6.00 + (0.051 \times PMA)$</td>
<td>0.63</td>
<td>0.14</td>
<td></td>
</tr>
</tbody>
</table>

1 RVNO, right vomeronasal organ; LVNO, left vomeronasal organ; RVNE, right vomeronasal epithelium; LVNE, left vomeronasal epithelium.

2 Linear regression equations are based on the regression equation $Y = a + (b \times PMA)$; PMA, postmenstrual age (in weeks); N, sample size.

3 S.E., standard error of the slope.

*p < 0.05; †p > 0.05, not significant.

The timing of VNE volume increase corresponded to that for overall VNO volume, demonstrating the importance of epithelial size increase to overall VNO growth. These histological and quantitative findings indicate that the VNE grows in a time period when internal architectural changes occur in the VNO. Previous suggestions that the vomeronasal epithelium becomes relatively thinner with increased age (Chouard et al., 1972; Jordan, 1972) are therefore impressions based on the relative cross-sectional dimensions of the lumen and do not take changing VNE volume into account.

A comparison of data from the present study with previous findings on VNO length may facilitate an understanding of the degree of prenatal VNO growth. Although fetal aging methods differ, the present findings are similar to those of previous studies on fetuses of a similar sitting height range. Ishimitsu (1958) reported a VNO length range of 0.22-2.97 mm (220-2,970 µm) for a fetal sample of 36-310 mm in sitting height, and the present sample (29-280 mm sitting height) exhibited an overall VNO length range of 247-3,015 µm. The present findings are also consistent with the neonatal VNO length estimates of Noyes (1935) of 2.5 mm (2,500 µm) maximum length. Length estimates for the adult human VNO are rare, and methods of measurement differ and sometimes are unstated. Jordan (1972) provided VNO lengths of 10-11 mm (10,000-11,000 µm) for two adults. Fenu (1959) measured the VNO at 15 mm (15,000 µm). Most recently, Stensaas et al. (1991) provided a length estimate of the adult human VNO based on an unstated
number of specimens from recent autopsies. These VNOs were injected with India ink fixative and were estimated to range between 5 and 10 mm (5,000-10,000 µm), which the investigators stated may have been an underestimation. The most extreme measures noted for adult VNO lengths were from Ishimitzu (1958) of 2.52 mm (2,520 µm, based on histological sections) and 62 mm (62,000 µm), a gross measurement by Mangakis (1901). Such results suggest that the adult human VNO may exhibit a great deal of variation in length, but much of this variation may be due to differing measurement methods. When compared with the data from the present study, most adult VNO length approximations suggest that some late prenatal or postnatal length increase must occur.

The results of the present study also suggest fetal VNO dimorphism between sexes. This possibility should not be overlooked because of several recent studies. Segovia and Guillamón (1982, 1993) found larger VNO volumes (although not presented relative to somatic measures) and more numerous sensory receptors in male than in female rats. Intersex differences were also noted in human VNO function in which some putative human pheromones ("vomeropherins") were detected only by females, whereas others were detected only by males (Monti-Bloch et al., 1994; Berliner et al., 1996). Potential functions of pheromonal communication in humans have long been known and may be very specific in females. For instance, menstrual synchrony has been noted in human VNO function in which some putative human pheromones ("vomeropherins") were detected only by females, whereas others were detected only by males (Monti-Bloch et al., 1994; Berliner et al., 1996). Potential functions of pheromonal communication in humans have long been known and may be very specific in females. For instance, menstrual synchrony has been noted in human VNO function in which some putative human pheromones ("vomeropherins") were detected only by females, whereas others were detected only by males (Monti-Bloch et al., 1994; Berliner et al., 1996). Potential functions of pheromonal communication in humans have long been known and may be very specific in females. For instance, menstrual synchrony has been noted in human VNO function in which some putative human pheromones ("vomeropherins") were detected only by females, whereas others were detected only by males (Monti-Bloch et al., 1994; Berliner et al., 1996). Potential functions of pheromonal communication in humans have long been known and may be very specific in females. For instance, menstrual synchrony has been noted in human VNO function in which some putative human pheromones ("vomeropherins") were detected only by females, whereas others were detected only by males (Monti-Bloch et al., 1994; Berliner et al., 1996). Potential functions of pheromonal communication in humans have long been known and may be very specific in females. For instance, menstrual synchrony has been noted in human VNO function in which some putative human pheromones ("vomeropherins") were detected only by females, whereas others were detected only by males (Monti-Bloch et al., 1994; Berliner et al., 1996). Potential functions of pheromonal communication in humans have long been known and may be very specific in females. For instance, menstrual synchrony has been noted in human VNO function in which some putative human pheromones ("vomeropherins") were detected only by females, whereas others were detected only by males (Monti-Bloch et al., 1994; Berliner et al., 1996). Potential functions of pheromonal communication in humans have long been known and may be very specific in females. For instance, menstrual synchrony has been noted in human VNO function in which some putative human pheromones ("vomeropherins") were detected only by females, whereas others were detected only by males (Monti-Bloch et al., 1994; Berliner et al., 1996). Potential functions of pheromonal communication in humans have long been known and may be very specific in females. For instance, menstrual synchrony has been noted in human VNO function in which some putative human pheromones ("vomeropherins") were detected only by females, whereas others were detected only by males (Monti-Bloch et al., 1994; Berliner et al., 1996).
Meredith, 1987), such as estrus suppression (Lee-Boot effect) and subsequent estrus release in the presence of males (Whitten effect).

In the present study, significant differences in VNO length between sexes reveal shape dimorphism only and may not be correlated with functional differences. The differences noted may also be due to differing sample distributions. Although the age range was similar (8-28.5 in females, 10-30 weeks in males), the sample of males was substantially larger in the range of 10-14 weeks, which may have affected the regression line slopes. However, the divergence of the VNE and VNO volume regression lines was initially similar between sexes and diverged markedly between 16 and 30 weeks, suggesting greater overall prenatal growth of the VNO in females. Based on this sample, divergent regression lines were noted previously between sexes for VNO but not PC measures (Smith et al., 1996b). Although these results should be viewed with caution due to the sample distributions and small sample sizes by sex, postnatal comparisons are warranted.

The findings of the present study demonstrate prenatal volumetric growth of the VNE and suggest that continued prenatal/postnatal length increase occurs. Such results are difficult to reconcile with suggestions of fetal human VNO degeneration (Humphrey, 1940; Nakashima et al., 1985; Kjaer and Fischer Hansen, 1996). This renders suggestions of fetal VNO degeneration unlikely, and calls into question the view of the human VNO as a functionless structure. However, it is clear that the present sample must be compared with histologically sectioned adult human specimens to better establish a continuous growth of the VNO. Volume appears to be the most meaningful measure for future studies because it takes into account the changing thickness of the VNE.

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GROWTH OF THE HUMAN FETAL VOMERONASAL ORGAN


