CT Scans Imaging of Human Ethmoid Sinuses and Gross Anatomical Dissection: a Descriptive, Projective, Comparative, and Dimensional Study

Mohammad Ahmad ABDALLA¹, Rana Zahim HUSSIEN²

Abstract

Introduction: The ethmoid air sinus can subdivide into several air cells, which are separated from each other by thin, incomplete bony septa resulting in the formation of three groups of air cells (anterior, middle, and posterior cells). Methods: A randomized sample of 360 human individuals, including 110 cadavers with another 250 CT scan cases, was achieved from February 2020 to November 2021. Results: The agger nasi was the most common type of cell demonstrated by 81.8% in cadaveric cases and 94% in CT cases. The frontal bulla cell presents just above the ethmoidal bulla and may produce convexity on the frontal sinus floor. Its prevalence was 10.9% in cadaveric cases and 22.8% in CT cases. The suprabullar cell is on top of bulla ethmoidalis and represents 7.3% of cadaveric cases and 14.8% of CT cases. Concha bullosa presents as a comprehensive pneumatization in the middle turbinate. Its prevalence was 34.5% in cadaveric cases and 44% in CT cases. The Haller cell reveals as a pneumatized air-filled cell shown at the lower medial side of the orbit. It was in 29% of cadaveric cases and 42% of CT cases. In addition, the sphenoethmoid (Onodi) cell is a posterior ethmoidal cell with a prevalence of 41.8% in cadaveric and 64% in CT cases. Conclusion: This study described the morphologic anatomy of each ethmoid sinus and compared its dimensions by gross anatomy with CT scanning in different age groups. This yields clues to understanding the variations in human races and ethnic groups.

Keywords: CT scan images, human anatomy, dissection, ethmoid sinus.

¹Department of Human Anatomy, Tikrit University College of Medicine, Tikrit, Iraq
²Radiologist, M.Sc. / Salah Aldeen General Hospital, Salah Aldeen Health Directorate, Tikrit, Iraq

Corresponding author:
Mohammad Ahmad ABDALLA, Department of Human Anatomy, Tikrit University College of Medicine, Yarmook Street, Box 45, Tikrit, 28001, Iraq
E-mail: dr.mohammad68@tu.edu.iq
INTRODUCTION

Anatomy of Ethmoid Sinuses

The ethmoid air sinus occupies the lateral masses (labyrinths) of ethmoid bone between the medial orbital and lateral nasal walls. The borders of the ethmoid sinus are incomplete and are covered by adjacent bones. Furthermore, each sinus is subdivided into several air cells, which separated from each other by thin, incomplete bony septa, result in formation of three groups of air cells (anterior, middle and posterior cells). However, some anastomosis combines the anterior and middle air cells as a single anterior group. The distinct and clear division between both major ethmoidal sinuses is characterized by the middle turbinate’s basal lamella. The anterior ethmoidal sinus contains clefts and cells, which drain or open inferiorly and anteriorly to the mentioned lamella. In a similar way, the posterior ethmoidal complex contains those clefts and cells, which drain or open superiorly and posteriorly.

The middle turbinate’s basal lamella is really the ethmoturbinals’ third basal lamella. The maxillary crista ethmoidalis is neighbor to the most superior and anterior insertion of this middle turbinate. While the lamina perpendicularis, which is the crista ethmoidalis belongs to the perpendicular process of the palatine bone is joined to its posterior end. The region between comprises three portions: the middle turbinate’s anterior third installs in vertical direction into the base of the skull at the lateral margin of cribriform plate (lamina cribrosa); while the middle third tends to turn laterally throughout the base of the skull to the lamina papyracea (orbital lamina), where it ultimately turned inferiorly; but the most posterior portion becomes horizontal.

The “infundibulum ethmoidale”, which is a fissure or cleft, or actual three-dimensional gap, is the most significant among other infundibula. The uncinate process medially and the orbital lamina laterally border the ethmoid infundibulum. Antero-superiorly, the frontal processes of the lacrimal and maxillary bones may form portions of the lateral border. The inferior turbinate is connected by union with the anterior edge of the uncinate process. The ethmoid infundibulum has a V-like form in axial CT scan sections because it ends abruptly in an acute angle at its frontal end. It continues posteriorly to the anterior aspect of the bulla ethmoidalis, and via the hiatus semilunaris inferior, it drains into the middle meatus.

The ethmoidal bone is accessible superiorly, lateral to middle turbinate insertion and the lamina cribrosa. Frontal bone is the one that makes the ethmoidal roof. The ethmoidal cells and clefts are covered by foveolae or indentations in the frontal bone. Its roof, the thinnest bone in whole frontal skull base, can be classified into three groups based on the length of cribriform plate’s lateral lamella. This is the arrangement that the surgeon is most concerned about because instruments might potentially enter the thin and susceptible lateral lamella.

The recessus sphenoidalis (sphenoidal recess) is the gap between both the superior (and supreme, if exist) turbinates laterally, the nasal septum medially, and the nasal roof (rima olfactoria) superiorly. The sphenoid bone’s anterior aspect forms its posterior margin. There is really no obvious inferior margin medially, and the inferior margin is visible laterally at the inferior border of superior turbinate. While the anterior extend, which runs into the common nasal meatus, is also ill-defined.

The cellular sphenoidal cells or Onodi cells are posterior ethmoidal cells that have been pneumatized widely laterally and to a degree above the sphenoid sinus. In some people, the optic nerve is intimately against the sphenoid cell wall without exhibiting an indentation. Several posterior ethmoidal cells may also have an indentation from the optic nerve into these sinus cells.

This study aims to describe the morphologic anatomy of the ethmoid paranasal air sinuses, determine their dimensional measurements by gross anatomy and compare these findings with the corresponding findings obtained from CT scanning in different age groups of both genders in different planes.

MATERIALS AND METHODS

Selection of the sample

A randomized sample of 360 human bodies; including 110 cadavers dissected at Forensic Medicine Unit in Salah Aldeen General Hospital and the Institute of Forensic Medicine in Baghdad, while the another 250 cases were evidently healthy normal individuals who attended at the CT scanning Unit in both Medical City Teaching Hospital and Salah Aldeen General Hospital. This study was achieved during February 2020 to November 2021.
This study was given approval code number by the Tikrit University College of Medicine / Medical Ethics Committee (IQ.TUCOM.REC.2020.716). All participants in the current study provided an ethical standard consent statement concerning the Helsinki Declaration by the World Medical Association, which was updated in 2000 at Edinburgh.

One hundred and ten human cadavers arranged in four various age groups of approximately equal number of males and females healthy bodies as in in Table 1.

### Table 1. Distribution of participating human cadavers according to age and gender.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Age</th>
<th>Male No.</th>
<th>Female No.</th>
<th>Total No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>20 – 29 years</td>
<td>16</td>
<td>14</td>
<td>30</td>
</tr>
<tr>
<td>Group 2</td>
<td>30 – 39 years</td>
<td>14</td>
<td>11</td>
<td>25</td>
</tr>
<tr>
<td>Group 3</td>
<td>40 – 49 years</td>
<td>13</td>
<td>12</td>
<td>25</td>
</tr>
<tr>
<td>Group 4</td>
<td>50 – 59 years</td>
<td>15</td>
<td>15</td>
<td>30</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>58</td>
<td>52</td>
<td>110</td>
</tr>
</tbody>
</table>

This study comprised 250 healthy persons attending hospital to do CT scan images of the human sinuses. These individuals were of male and female and grouped as in in Table (2).

### Table 2. Distribution of participating CT imaging persons according to age and gender.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Age</th>
<th>Male No.</th>
<th>Female No.</th>
<th>Total No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>20 – 29 years</td>
<td>35</td>
<td>30</td>
<td>65</td>
</tr>
<tr>
<td>Group 2</td>
<td>30 – 39 years</td>
<td>32</td>
<td>31</td>
<td>63</td>
</tr>
<tr>
<td>Group 3</td>
<td>40 – 49 years</td>
<td>30</td>
<td>28</td>
<td>58</td>
</tr>
<tr>
<td>Group 4</td>
<td>50 – 59 years</td>
<td>33</td>
<td>31</td>
<td>64</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>130</td>
<td>120</td>
<td>250</td>
</tr>
</tbody>
</table>

### Criteria for sample’s inclusion and exclusion

The current study implicated patients who complained of headaches and who were admitted to the radiology clinic to get CT images for the brain and the paranasal sinuses that show no abnormal observations in the human sinuses.

In addition, patients who had previous history of surgery, or trauma, or any other pathological lesions in maxillofacial region were excluded out of this study.

While the human cadavers dissected in this study were of those individuals that sent for dissection at the forensic medicine in order to find out the death cause which neither due to the respiratory system nor head region disease. Therefore, any cadaver with brain tumor, head injury, maxillofacial region trauma, or other neighbor areas was excluded from this study.

### DISSECTION:

For these 110 specimens, the anatomical dissection was performed using particular gross anatomy of the head area utilized and digitally photographed for more examination, measurement and comparison. This dissection of fresh human tissues was done precisely and carefully to approach the different structures that in association with the ethmoid paranasal sinuses, which were the focus of the current study.

The head was attached firmly to a wooden block and fixed with screws in order to achieve precise sagittal slices revealing the ethmoid paranasal sinuses. Then, using an orthopedic band saw or a sharp manual saw with extremely tiny teeth to form a quite thin sheet layering in dissection.

Using a flexible tape measure, laser distance measure or vernier caliper to measure the dimensions of each ethmoid sinus and recorded the dimensional results.

### Spiral CT scan examination and patient positioning

Spiral CT scans were performed on all of the individuals without the use of anesthesia or contrast media, and CT scanning of the ethmoid paranasal air sinuses had been acquired in the axial, coronal and sagittal planes.

Axial scans were taken with the individual supine on a monitoring table and the digital imaging gantry in a stable position as demonstrated in Figure 1A.

While the coronal scans are enabled by either prone or supine position with the patient’s chin was backup on a fixed head holder and his/her head was in back extension position as far as possible and angling of
the digital imaging gantry to approximate the sinus coronal plane. This is due to the fact that the very fine overlapping sections produced on contemporary multidetector scanners may be processed to resemble a native coronal scan in quality as obvious in Figure 1B.

**Figure 1A.** For axial CT scanning, the patient lies in supine position on the CT examination table with the head is in the head rest site.

**Figure 1B.** For coronal CT scanning, the patient lies in prone positioning with the chin is supported on the fixed head holder and his/her head should be extended back as far as possible.

Computer-generated reconstructive coronal images from the thinner axial slices can be developed for individuals who cannot stand the prone posture requested for coronal cutting.

Most skull-base and sinonasal structures may be investigated using 5 mm sections, while smaller lesions and the ostiomeatal unit are best examined with 3 mm sections. The intermediate window width/level (W/L) procedure (2500/250, W/L) was recommended for filming. Fast capture of nearly isotropic voxels and covering of the interest volume are among the benefits of multislice technology in CT scanning of any paranasal sinus. The latter yields a high multiplanar reorganization of the given data, which is best to be obtained in an axial plane.\(^ {12-15}\)

The imaging protocols used was 3-5 mm slices thickness, 94 mAs, 140 kVp, 400 window level, 2000 window width; (35-45) second scan time for ethmoid paranasal sinuses.

**Data processing**

Using the CT Siemens workstation’s 3D software, with optimum resolution (1280x1042), full-screen mode, and an image size (360 mmx288 mm).

The workstation allowed simultaneous visualization of a given reference spot in three aspects, sagittal, coronal, and axial, as well as images capture in JPEG formats in the illustration sections. Finally, the images were directly downloaded to a CD.

A Panasonic HD-H80 camera was used for the digital images of the specimens.

**Statistical analysis**

The collected information was transformed into a digital data structure. An experienced statistician's opinion was needed. The SPSS version 26 was used to aid with statistical analyses. At First, a frequency distribution used for the study variables.

The final quantitative variables (measurements) had been normally distributed; therefore mean, standard deviation, and basic statistical significance values were utilized to characterize them. The statistical significance difference in the mean among more than two groups was tested using ANOVA. The mean ± standard deviation was used to describe the range of expected outcomes for each measurement. In this research, a statistically significant P value was less than 0.05 was a significant level.

**RESULTS**

1. Anatomy of ethmoid sinus

By the anatomical dissection as shown in Figure 2A, (B), (C), the ethmoid was distinct from all other sinuses throughout that it’s the only sinus with very thin bone wall lamellae. Whereas the other sinuses may generate septations, they were far more solid and durable. As a result, those really thin bony structures and cells might easily migrate into neighboring bones or even other
sinuses. Extramural extensions might be moved into the frontal cells, frontal recess cells, infraorbital cells, and/or supraorbital cells, or indeed any combination of these cells. This important notion explains why ethmoidal sinus cell morphologies differ: extramural migration can take distinct pathways, resulting in diverse morphologies. As a result, there is no regularity among intramural cells with lamellae, leading in the formation of the ethmoidal labyrinth in which single cell might surpass its neighbor and push it to move in a manner different than the one in which it was mainly oriented.

With the CT images, particularly axial sections, the ethmoid cells complex exhibits a wedge shape. The front borders are narrower close to nasal bones, whereas the posterior borders opposing the sphenoid seem to be wider. As a result, the orbital borders are inclined somewhat away from the mid-sagittal axis. Surfaces from the three separate bones make up the medial orbital wall: sphenoid, ethmoid, and lacrimal. The lacrimal bone creates the lacrimal fossa and covers part among the most anterior ethmoidal cells on the anterior side. The anterior border of sphenoid bone forms a tiny piece of an orbital wall posteriorly. The lamina papyracea that makes up the bulk of the medial wall of the orbit is often quite thin and inadequately ossified that one looks incomplete with CT scans.

The cribriform plate forms the nasal cavity roof. There are numerous ways to spot them. First, at the midline, the crista galli sits directly on the outer part of the cribriform plate which was shown in 30% of cadaveric cases and 34% of CT scanning cases. Second, at the midline, the nasal septum connects to the undersurface of the cribriform plate with a prevalence of 22.7% in cadaveric cases and 31.2% in CT scanning cases. Third, the central turbinates adhere to the cribriform plates’ lateral borders and the roof of ethmoid locates more cephalic on each side and this finding obvious in 47.3% of cadaveric cases and 34.8% of CT scanning cases. These relations were easily demonstrated in coronal sections.

The all above findings were well recognized in cadaveric dissection; however the CT finding recognized the following structures more precisely:–

A: Agger nasi cell
In the present study, it appears as the ethmoidal cell with the most anterior position. The anterior extremity of uncinate process is regarded the topographical

---

**Figure 2.** Sagittal cadaveric dissection to the lateral nasal wall:

**Figure 2 A** showing: 1-Shadow for the superior part of nasolacrimal duct. 2-The uncinate process. 3-The agger nasi. 4-The middle turbinate. 5-The superior turbinate. 6-The supreme turbinate.

**Figure 2 B** showing: 1-The agger nasi. 2-Shadow for the inferior part of nasolacrimal duct. 3-The bulla ethmoidalis. 4-The retrobullar recess. 5-The hiatus semilunaris inferioris.

**Figure 2 C** showing: 1-The superior meatus. 2-Opening of the posterior ethmoid sinus. 3-The basal lamella of the middle turbinate.
site of the agger nasi, and additional pneumatization of agger involves the migrating of ethmoidal cells towards the lacrimal bone, enhancing the lateral nasal wall prominence. The lacrimal bone regarded indeed as an impressive sight because it marks the boundary between both the frontal processes of the maxilla and the frontal bone.

When evaluating a coronal CT scanning from anterior to posterior, the very first air cell is evident as a bulge along on lateral wall of the nose and anterior to the vertical connection of the middle turbinate. It was the commonest type of cell that seen in 81.8% of cadaveric cases and 94% of CT scanning cases, in both, the sagittal and coronal CT sections as shown in Figure 3A.

**B: Frontal bulla cell**
This cell may be seen as an ethmoidal cell just above ethmoidal bulla that pneumatizes from posterior frontal recess into the frontal sinus. Its posterior border is the cranial fossa, whereas its anterior wall must extend towards frontal sinus. Thus, it is situated behind the pneumatization tract of the real frontal sinus and can represent pneumatization of bulla ethmoidalis anterior wall and behind the anterior ethmoidal artery course as revealed in Figure 2D. It may produce convexity mostly in frontal sinus floor; with a prevalence 10.9% in cadaveric cases and 22.8% in CT scanning cases that was seen on sagittal CT section as shown in Figure 3B.

**C: Suprabullar cell**
In the present study, this cell found as an ethmoidal cell on top of bulla ethmoidalis with its superior border is the anterior cranial fossa. Its anterior wall may not extend towards the frontal sinus; therefore, it can represents the pneumatization of bulla ethmoidalis anterior wall. This finding was represented in 7.3% of cadaveric cases and 14.8% of CT scanning cases which was well shown on sagittal CT section as shown in Figure 3C.

It resembles the suprabullar recess in appearance (The suprabullar recess and suprabullar cell cannot be distinguished with a CT scan alone).

**D: Concha bullosa**
It present as a comprehensive pneumatization of middle turbinate and regarded as anatomic variation of this research. A considerable pneumatization degree that was observed to indicate the existence of a concha bullosa. This finding was with a prevalence 34.5% of cadaveric cases and 44% of CT scanning cases which was well seen on coronal and axial sinus CT sections as demonstrated in Figure 3D.

**E: Haller cell**
The present study reveals it as a pneumatized air-filled cell that shown at the lower medial side of the orbit creating the upper roof of human maxillary sinus ostium. The lower medial portion of the orbit’s floor serves as the cell’s lateral border. This kind of cell found in 29% of cadaveric cases and 42% of CT scanning cells which best seen on axial and coronal sinus CT images as shown in Figure 3E.

**F: Sphenoethmoid cell (Onodi cell)**
This cell regarded as a posterior ethmoidal cell which obviously extended posteriorly across the sphenoid sinus’s anterior wall, when this cell can or cannot involve the optic nerve. Onodi cells are the cells that originate from the ethmoidal bone inside the sphenoidal bone. Its prevalence was 41.8% of cadaveric cases and 64% of CT scanning cases that was seen on sagittal sinus CT section as seen in Figure 2E, Figure 3F.
CT Scans Imaging of Human Ethmoid Sinuses and Gross Anatomical Dissection

**Figure 2** E showing: 1- The sphenoethmoid cell. 2- The infraoptic recess.

**Figure 3.** CT scanning sections:

**Figure 3A.** Coronal section showing:
1- the agger nasi cell as the most anterior ethmoid.

**Figure 3B.** Sagittal section showing:
1- The frontal bullar cell. 2- The bulla ethmoidalis.

**Figure 3C.** Sagittal section showing:
1- The suprabullar cell. 2- The bulla ethmoidalis.

**Figure 3D.** Axial section showing:
1- The concha Bullosa of the middle turbinate.

**Figure 3E.** Coronal section showing:
1- The Haller cell. 2- The drainage of sinus ostium.
2. Ethmoid sinus measurements done on dissected human cadavers:

Since the walls of the ethmoid air sinuses were incomplete; therefore, there was no definitive limit of any dimension of the subdivisions of the ethmoidal sinus which are the anterior, middle and posterior sinuses. So that the ethmoidal sinus result in formation of single large labyrinth-shape cavity but with different positioned air cells with their three different ostia that opened in three different sites.

i. Ethmoid sinus length done on dissected human cadavers:

In men, the mean for the right ethmoid sinus length was 22.0±7.4 mm, while the mean of the left ethmoid sinus length was 29.1±5.5 mm. While in women, the mean of the right ethmoid sinus length was 26.6±5.3 mm, while the mean for the left ethmoid sinus length was 27.1±4.6 mm as shown in Table 3.

The mean value for right ethmoid sinus length in females was significantly elevated than males (p<0.05), whereas the mean value of left ethmoid sinus length of males was statistically significant than that for females as observed in Table 3.

Depending on age group, the maximum length of the ethmoid sinus in men recorded in group 2 on the right side with 23.2±5.3 mm, as noted in Table 4.

Utilizing ANOVA test, obvious statistically significant differences (p<0.05) in mean reported values of both sides amongst the studied age groups in males and only for right side in females as shown in Table 4.

ii. Ethmoid sinus width done on dissected human cadavers:

For men, the mean value of right ethmoid sinus width was 14.4±3.8 mm, but the mean value of left ethmoid sinus width was 12.1±3.9 mm. While for women, the mean value of right ethmoid sinus width was 13.6±3.7 mm, but the mean value for left sinus width was 10.3±4.1 mm as shown in Table 3.

Regarding gender difference, the mean values of ethmoid sinus width for both sexes were not statistically significant differences (p>0.05) as mentioned in Table 3.

As cadavers grouped according to age, the maximum width for the ethmoid sinus in men reported in group 3 on the right side with 15.5±3.8 mm, but the minimum width recorded in group 2 on the left side with 11.4±3.7 mm. While in women, the maximum width of the sinus reported in group 3 on the right side with 13.4±3.7 mm and the minimum width recorded in group 1 on the left side with 9.8±4.3 mm, as clear in Table 4.

As ANOVA test used, the variation in mean amongst the age groups of each gender was not statistically significant difference (p>0.05) as shown in Table 4.

iii. Ethmoid sinus height done on dissected human cadavers:

In males of the present study, the mean value for right ethmoid sinus height was 23.1±3.8 mm while the mean value for left ethmoid sinus height was 24.5±4.0 mm, whereas in females, the mean value for right ethmoid sinus height was 19.7±3.6 mm and the mean height for the left side was 21.1±3.7 mm as shown in Table 3.

Regarding gender difference, males recordings were higher significance than that for females (p<0.05) as demonstrated in Table 3.

When cases arranged according to their age, the maximum height for the ethmoid sinus of males reported in group 2 of the right side with 25.2±5.3 mm while the minimum height recorded in group 3 for the right side with 20.1±3.7 mm, and in females the maximum height for the sinus recorded in group 3...
for the left side with 22.1±3.5 mm but the minimum height reported in group 2 for the right side with 18.3±3.5 mm, as noted in Table 4.

The difference in the mean values between the four age groups in both genders of the right ethmoid sinus height was showed statistically significant difference (p<0.05), as tested by ANOVA as shown in Table 4.

### Table 3. Ethmoid sinus measurements for both genders done on human cadavers.

<table>
<thead>
<tr>
<th></th>
<th>Male</th>
<th>Female</th>
<th>Both Genders</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Range</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Right Ethmoid sinus length (mm)</td>
<td>(9.3 – 43.1)</td>
<td>22.0</td>
<td>7.4</td>
</tr>
<tr>
<td>Left Ethmoid sinus length (mm)</td>
<td>(12.5 – 46.6)</td>
<td>29.1</td>
<td>5.5</td>
</tr>
<tr>
<td>Right-left Ethmoid sinus length (mm)</td>
<td>(9.3 – 46.6)</td>
<td>25.6</td>
<td>6.4</td>
</tr>
<tr>
<td>Right Ethmoid sinus width (mm)</td>
<td>(3.2 – 25.6)</td>
<td>14.4</td>
<td>3.8</td>
</tr>
<tr>
<td>Left Ethmoid sinus width (mm)</td>
<td>(7.4 – 21.2)</td>
<td>12.1</td>
<td>3.9</td>
</tr>
<tr>
<td>Right-left Ethmoid sinus width (mm)</td>
<td>(3.2 – 25.6)</td>
<td>13.2</td>
<td>3.8</td>
</tr>
<tr>
<td>Right Ethmoid sinus height (mm)</td>
<td>(8.6 – 33.7)</td>
<td>23.1</td>
<td>3.8</td>
</tr>
<tr>
<td>Left Ethmoid sinus height (mm)</td>
<td>(8.4 – 40.1)</td>
<td>24.5</td>
<td>4.0</td>
</tr>
<tr>
<td>Right-left Ethmoid sinus height (mm)</td>
<td>(8.4 – 40.1)</td>
<td>23.8</td>
<td>3.9</td>
</tr>
</tbody>
</table>

### Table 4. Age difference of ethmoid sinus measurements for both genders done on human cadavers.

<table>
<thead>
<tr>
<th></th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
<th>Group 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Range</td>
<td>Mean</td>
<td>SD</td>
<td>Range</td>
</tr>
<tr>
<td>Male</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right Ethmoid sinus length (mm)</td>
<td>(10.3 – 42.7)</td>
<td>24.3</td>
<td>6.5</td>
<td>(12.4 – 40.2)</td>
</tr>
<tr>
<td>Left Ethmoid sinus length (mm)</td>
<td>(12.5 – 40.1)</td>
<td>30.3</td>
<td>5.6</td>
<td>(13.3 – 42.5)</td>
</tr>
<tr>
<td>Right Ethmoid sinus width (mm)</td>
<td>(5.4 – 25.6)</td>
<td>13.4</td>
<td>3.7</td>
<td>(3.2 – 28.9)</td>
</tr>
<tr>
<td>Left Ethmoid sinus width (mm)</td>
<td>(9.3 – 22.1)</td>
<td>11.7</td>
<td>4.0</td>
<td>(7.8 – 27.4)</td>
</tr>
<tr>
<td>Right Ethmoid sinus height (mm)</td>
<td>(8.6 – 35.4)</td>
<td>23.8</td>
<td>3.6</td>
<td>(10.5 – 36.2)</td>
</tr>
<tr>
<td>Left Ethmoid sinus height (mm)</td>
<td>(10.7 – 38.3)</td>
<td>24.6</td>
<td>4.1</td>
<td>(9.2 – 40.1)</td>
</tr>
<tr>
<td>Female</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right Ethmoid sinus length (mm)</td>
<td>(7.6 – 37.4)</td>
<td>27.3</td>
<td>5.5</td>
<td>(9.7 – 39.8)</td>
</tr>
<tr>
<td>Left Ethmoid sinus length (mm)</td>
<td>(13.7 – 44.6)</td>
<td>26.8</td>
<td>4.8</td>
<td>(11.1 – 45.7)</td>
</tr>
<tr>
<td>Right Ethmoid sinus width (mm)</td>
<td>(3.5 – 29.1)</td>
<td>12.6</td>
<td>3.7</td>
<td>(3.8 – 29.8)</td>
</tr>
<tr>
<td>Left Ethmoid sinus width (mm)</td>
<td>(6.3 – 27.2)</td>
<td>9.8</td>
<td>4.3</td>
<td>(4.7 – 23.3)</td>
</tr>
<tr>
<td>Right Ethmoid sinus height (mm)</td>
<td>(8.3 – 33.3)</td>
<td>20.2</td>
<td>3.8</td>
<td>(5.6 – 34.2)</td>
</tr>
<tr>
<td>Left Ethmoid sinus height (mm)</td>
<td>(13.6 – 36.5)</td>
<td>20.8</td>
<td>3.9</td>
<td>(15.8 – 34.2)</td>
</tr>
</tbody>
</table>

### 3. Ethmoid sinus measurements done by CT

#### i. Ethmoid sinus length done by CT

The mean value for the right ethmoid sinus length in males was 20.3±5.2 mm and was 22.2±4.8 mm on the left side. Whereas, the mean value for the right ethmoid sinus length in females was 21.9±5.6 mm and on the left side the recorded mean value was 25.2±4.7 mm. There was a significant side difference seen in females only (p<0.05) as seen in Table 5.

Regarding gender differences, the left ethmoid sinus length in females was significantly higher than in males, whereas the right sinus showed no significant difference in both genders, as given in Table 5.

For different age group of the current study, the maximum length of the ethmoid sinus for males demonstrated in group 2 on the left side 23.5±4.8 mm, whereas the minimum length demonstrated in group 1 on the right side 19.7±4.8 mm. While in female cases, the maximum length for the sinus demonstrated in group 1 on the left side 27.4±4.8 mm while the minimum length demonstrated in group 1 on the right side 19.8±6.1 mm, as clear in Table 6.
ANOVA test also was used for the four age groups and represented a statistically significant differences in both sides of both genders (p<0.05), except in the right ethmoid sinus of male cases which recorded no significant differences between these groups (p>0.05), as shown in Table 6.

ii. Ethmoid sinus width done by CT:
For males, the mean of right ethmoid sinus width was 12.0±3.2 mm and the mean width of the left ethmoid sinus was 8.5±2.8 mm. For females, the mean right ethmoid sinus width was 9.2±3.2 mm but the mean left ethmoid sinus width was 7.9±2.9 mm. Male cases showed high statistical significance side difference (p<0.05), whereas female cases showed no significance side difference (p>0.05), as recorded in Table 5.

In terms of gender differences, just the right ethmoidal sinus width in males was significantly greater than in females, as shown in Table 5.

<table>
<thead>
<tr>
<th>Table 5. Ethmoid sinus measurements for both genders done by CT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Male</strong></td>
</tr>
<tr>
<td>Range</td>
</tr>
<tr>
<td>Right Ethmoid sinus length (mm)</td>
</tr>
<tr>
<td>Left Ethmoid sinus length (mm)</td>
</tr>
<tr>
<td>Right-left Ethmoid sinus length (mm)</td>
</tr>
<tr>
<td>Right Ethmoid sinus width (mm)</td>
</tr>
<tr>
<td>Left Ethmoid sinus width (mm)</td>
</tr>
<tr>
<td>Right-left Ethmoid sinus width (mm)</td>
</tr>
<tr>
<td>Right Ethmoid sinus height (mm)</td>
</tr>
<tr>
<td>Left Ethmoid sinus height (mm)</td>
</tr>
<tr>
<td>Right-left Ethmoid sinus height (mm)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 6. Age difference of ethmoid sinus measurements for both genders done by CT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group 1</strong></td>
</tr>
<tr>
<td>Range</td>
</tr>
<tr>
<td>Right Ethmoid sinus length (mm)</td>
</tr>
<tr>
<td>Left Ethmoid sinus length (mm)</td>
</tr>
<tr>
<td>Right Ethmoid sinus width (mm)</td>
</tr>
<tr>
<td>Left Ethmoid sinus width (mm)</td>
</tr>
<tr>
<td>Right Ethmoid sinus height (mm)</td>
</tr>
<tr>
<td>Left Ethmoid sinus height (mm)</td>
</tr>
<tr>
<td>Right Ethmoid sinus height (mm)</td>
</tr>
<tr>
<td>Left Ethmoid sinus height (mm)</td>
</tr>
<tr>
<td>Right Ethmoid sinus width (mm)</td>
</tr>
<tr>
<td>Left Ethmoid sinus width (mm)</td>
</tr>
<tr>
<td>Right Ethmoid sinus height (mm)</td>
</tr>
<tr>
<td>Left Ethmoid sinus height (mm)</td>
</tr>
</tbody>
</table>
on the right side 10.5±3.6 mm as well as the minimum width reported in group 4 on the left side 6.7±3.1 mm, as can be seen in Table 6.

For age grouping, ANOVA test was used. Among the four age groups, a statistical significant difference recorded for both sides and in both genders (p<0.05) as shown in Table 6.

iii. Ethmoid sinus height done by CT:
The mean value of right ethmoid sinus height for male cases was 20.6±3.5 mm, while the left ethmoid sinus height reported a mean value 22.0±3.7 mm. For females, the mean value of the right ethmoid sinus height was 19.8±3.7 mm but for the left ethmoid sinus height was 20.8±3.6 mm. There was no statistical significant differences in the overall side difference (p>0.05) as shown in Table 5.

Both male and female cases also revealed no significant side difference, as seen in Table 5.

Regarding to Table 6, the current study noticed that the maximum height of the ethmoid sinus in male cases reported in group 1 on the left side 22.8±3.8 mm but the minimum height reported in group 3 on the right side 20.1±3.3 mm. While in females the maximum height of the sinus reported in group 4 on the left side 22.1±3.5 mm but the minimum height reported in group 4 on the right side 19.2±4.0 mm.

ANOVA test findings indicated statistically significant differences just in the left ethmoid sinus height for both genders amongst four groups (p<0.05) once the cadavers were categorized according to age, as shown in Table 6.

DISCUSSION

In this study the anatomical dissection, clarified the ethmoid was clearly different from all other human sinuses in the fact that it was the only sinus with relatively thin osseous wall lamellae, resulting in forming an ethmoidal labyrinth. By which one cell can outgrow its neighboring cell and push the latter cell to move in a manner other than the one toward which it was mainly directed, this finding agreed with Bulescu et al study. This significant gap might be explained by variations in sample populations, interpretations of Haller's cells, and sensitive technology, capable of detecting even tiny supraorbital cells.

The present study showed that the prevalence of frontal bulla cells was 10.9% in cadaveric cases which was very close to that found by Zinreich et al 10%; whereas in CT cases the present study revealed the prevalence of these cells as 22.8% which was higher than that of Vaid et al 9%13.

Studies on the incidence of the concha bullosa cells had also diversified widely among the investigators; therefore the incidence recorded by the cadaveric dissection studies were 9% by Sava et al 8%, 8% by Acikalin29, 11% by Apuhan et al 10 and 20% by Yiğit et al 31. While those by CT investigations were 33% by Tavora et al 32 and 36% by Koo 37. The incidence of concha bullosa cells of the current study was 34.5% in the cadaveric cases and 44% in the CT cases where any extent of pneumatization has been regarded important and documented in order to demonstrate the existence of the concha bullosa.

In comparison, the Haller cells incidence in the present study which was 29% in cadaveric cases and 42% in CT cases, to reports of other CT studies that ranged from 11% in Ramaswamy study to 45.1% in Abdalla et al study. This significant gap might be explained by variations in sample populations, interpretations of Haller's cells, and CT scanning methods.

Utilizing twenty-one adult human cadaveric heads which were examined using conventional axial and
coronal CT sections before afterwards undergoing anatomical dissection, Ali et al.\textsuperscript{16} focused on the accuracy of CT in locating the sphenoid ethmoid (Onodi) cell in contrast to the anatomical dissection. According to anatomical dissection, the incidence of these cells in his research was 39 \%, but it was 7 \% in CT scans. These results disagreed with the higher incidence of these cells in this study, since it was 41.8\% in cadaveric cases and 64\% in CT cases and the cause of this difference between the two studies may be due to the use of only the coronal sections in Ali et al.\textsuperscript{16} study, whereas the present study used coronal, axial and sagittal sections. Another two CT studies disagreed with the prevalence of present study and they done by Senturk et al.\textsuperscript{17} with 3\% and Al-Zaidi and Badr\textsuperscript{18} with 28.1\%. On the other side, two surgical studies were in agreement and very close to the prevalence of present study and these done by OuYang et al.\textsuperscript{19} 65\% and Kown et al.\textsuperscript{20} 60\%.

In the present study, the mean value for the ethmoid sinus length in males in the dissected cadavers cases were 25.6±4.9 mm and in females were 26.9±4.9 mm; while in the CT scanning cases, these findings for males were 21.3±5.0 mm and for females were 23.5±5.1 mm. By these results the mean value for the ethmoid sinus length was greater in females than males in cadaveric cases and more obviously in CT scanning cases.

The cadaveric cases of the present study were demonstrated with the mean values of the ethmoid sinus width for males 13.2±3.8 mm and for females 12.0±3.9 mm. Whereas, the mean values of the ethmoid sinus width for the CT scanning cases were 10.3±3.0 mm in male cases and 8.6±3.0 mm in female cases. Those results showing that the ethmoid sinus was broader in males than females in both cadaveric and CT scanning cases.

The mean value of the ethmoid sinus height of males in the human cadaveric cases of the present study, were 23.8±3.9 mm and in females were 20.4±3.6 mm, while the mean values of the ethmoid sinus height in the CT scanning cases were 21.3±3.6 mm in male cases and 20.3±3.6 mm in female cases. Therefore these findings noted that the ethmoid sinus height was significantly greater in males than females of the cadaveric cases only.

An anatomical research done by Hui et al.\textsuperscript{41} revealed that the dimensional measurements of the ethmoid sinus were 20×20×10 mm, whereas the corresponding findings in the present study were 26.2×12.6×22.1 mm, and the differences may be due to ethnic variations.

In this study, concerning group 1 of ethmoid sinus, it was demonstrated by the highest value among other age groups in two parameters; length of left side sinus in the female CT cases and height of left side sinus in the male CT cases. Whereas, group 1 demonstrated by the lowest value among all other age groups in three parameters; the length of right side sinus in CT cases of both genders and the width of left side ethmoid sinus in female anatomical cases. So that due to these few findings, group 1 of ethmoid sinus might showing a little growth changes.

Group 2 of ethmoid sinus of this study was demonstrated by the highest value among other age groups in five parameters that including; length of left side sinus of male anatomical and CT cases, the width of right side sinus in CT cases of both sexes, height of right side sinus of male anatomical cases. Whereas, group 2 demonstrated by the lowest value among all other age groups in four parameters; the length of right side sinus in anatomical cases of both genders, the width of left side sinus of male anatomical cases and the height of right side sinus in female anatomical cases. Eight of these nine findings demonstrated the group 2 of ethmoid sinus showing characteristic phenomena that includes increase in sinus length and decrease in width on its left side, in relation with reversed picture on the right side demonstrated by decrease in length and increase in width; there was no clear anatomical explanation for these growth changes.

In the current study, group 3 of ethmoid sinus found as the highest value among all other age groups by four parameters which including; the length of right side ethmoid sinus in female anatomical cases, the width of right side sinus in anatomical cases of both genders and the height of left side sinus in female anatomical cases. Besides, group 3 associated with the lowest value among all other age groups in two parameters which were the height of right sinus in male anatomical and CT cases. Thus, if most of these finding related to group 3 where taken in consideration, then these findings might revealed the maximum level of growth of ethmoid sinus occur at this age group.

Group 4 of the ethmoid sinus of the current study reported with the highest value among all other age groups in just one parameter that was the height of left side sinus in female CT cases. On other side, group 4 presented with the lowest value among all other age groups in three parameters; the width of left side sinus in CT case of both genders, the height of right side
sinus in female CT cases. Therefore, from the previous findings, group 4 might reveal regression in growth process of ethmoid sinus and mostly in its width.

In spite of long and deep searching, no previous study associated with determining the parameters of the ethmoid sinus according to age groups found before this study.

CONCLUSION

This study was a scientific attempt to describe the morphologic anatomy of each ethmoid sinus, compared its dimensions by gross anatomy with CT scanning in different age groups. In addition, to figure out the various cells present or related to each ethmoid sinus which eventually give new clues to understand the variations in human races and ethnic groups.

Compliance with ethics requirements. The authors declare no conflict of interest regarding this article. The authors declare that all the procedures and experiments of this study respect the ethical standards in the Helsinki Declaration of 1975, as revised in 2008(5), as well as the national law. Informed consent was obtained from all the patients included in the study.

ACKNOWLEDGMENTS

The authors are grateful to all doctors, staff and health workers at the Forensic Medicine Unit in Salah Aldeen General Hospital and the Institute of Forensic Medicine in Baghdad, as well as to doctors, technicians, and clinical staff of the CT scanning Unit in both Medical City Teaching Hospital and Salah Aldeen General Hospital for their exceptional cooperation and endless support in making this scientific study a success.

References

10. Abdalla MA. Pneumatization patterns of human sphenoid sinus associated with the internal carotid artery and optic nerve by CT scan. Ro J Neurol. 2020;19(4):244-251.
17. Soyka MB, Treumann T, Schlegel CT. The agger nasi cell and uncinate process, the keys to proper access to the nasolacrimal drainage system. Rhinology. 2010;48(3):364-367.


