ANATOMICAL VARIATIONS OF HUMAN PARANASAL SINUSES: COMPUTED TOMOGRAPHIC ANALYSIS.

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ABSTRACT
The present investigation presents the anatomical variations of the human paranasal sinuses using computed tomography scanning (CT scan). Paranasal sinus CT scans obtained from 300 subjects (120 male and 180 female) were analyzed. Their ages ranged from 15 to 55 years with a mean age (28.4±8.79).

The maxillary sinus revealed a number of anatomical variations in 30% of cases. They appeared in the form of septated sinus in 16%, sinus hypoplasia in 10 %, and the presence of a tooth in the sinus in 4% of the cases. Examination of the frontal sinus revealed extensive pneumatization of the sinus in 38%, hypoplasia in 26 % and aplasia in 4 % of the cases. CT examination of the sphenoidal sinus revealed sinus hypoplasia in 4%, extensive pneumatization of the sinus in 6 % and unseptated sphenoidal sinus in 10% of cases. Impression of the optic nerve on the wall of sphenoidal sinus was found in 60% of the cases. The internal carotid artery bulged within the lumen of the sphenoidal sinus in 50% of the cases. Anatomical variations of the ethmoid sinus detected by CT included Agger nasi cell (72%), sphenoethmoidal (Onodi) cell (70%), pneumatized middle turbinate (concha bullosa) (56%), enlarged ethmoid bulla (34%), infraorbital ethmoidal (Haller's) cell (30%), and paradoxically curved middle turbinate (20%). The uncinate process showed hypoplasia in 24%, elongation in 10%, pneumatization (uncinate
SUBJECTS AND METHODS
Consecutive CT scans of the paranasal sinuses obtained from 300 (120 males and 180 females) subjects after exclusion of those with previous alteration of the paranasal sinus anatomy due to facial trauma, paranasal sinus carcinoma, or previous sinonasal surgery. Their age ranged from 15 to 55 years with a mean age 28.4 ±8.79. They were referred from ENT, Ophthalmology, Neurology and Neurosurgery Departments for different reasons and were undergoing evaluation at the Department of Radiology, Mansoura University Hospital from 2003 to 2005. Coronal and axial CT scans were done for each subject. The coronal CT scans were taken from the glabella to the posterior clinoid processes and the axial scans were taken from the hard palate to above the frontal sinus (Figs. 1 & 2). This approach assured complete coverage of all the paranasal sinuses. All subjects were scanned on Toshiba Asteion unit with 5 mm sequential scan and window width = 1500 HU without the use of intravenous contrast (Zinreich et al., 1987). CT images were analyzed for the incidence of anatomical variations of the paranasal sinuses including excessive pneumatization, hypoplasia, septation and variations of bony walls of each sinus.

RESULTS
1- Anatomical variations of the maxillary air sinus (Table 1):
Normally, the floor of the maxillary sinus appeared formed by the alveolar process of the maxilla and the apices of the teeth were separated from the floor by a bone of varying thickness (Fig. 3). Septated maxillary sinus was present in 48 cases (16%) (Figs. 4 & 5) and maxillary sinus hypoplasia was detected in 30 cases (10%) (Fig. 6). A tooth was detected in the maxillary sinus in 12 cases (4%) (Figs. 7 & 8).

II. Anatomical variations of the frontal air sinus (Table 2):
Extensive pneumatization of the suprariary portion of the frontal bone with an apparent increase in the volume of the frontal sinus was detected in 114 cases (38%) (Figs. 9 & 10). Frontal hypoplasia was present in 78 cases (26%) (Fig. 11) and aplasia of the frontal sinus was detected in 12 cases (4%) (Fig. 12).
IV. Anatomical variations of the ethmoidal air sinuses (Table 4):

Normally, the Agger nasi is a non-pneumatized crest present anterior and superior to the middle turbinate (Fig.21). Agger nasi cell is a pneumatized Agger nasi. In coronal CT, this cell was seen below the level of the frontal sinus and anterior to the attachment of the middle turbinate in 216 cases (72%) (Figs.22 & 23).

Haller's cell (infraorbital ethmoidal cell) is an ethmoidal air cell appeared along the medial part of orbital floor. Haller's cell was detected in 90 cases (30%) (Figs.24 & 25). Onodi (sphenoethmoidal) cell is the most posterior ethmoid cell when it becomes extensively pneumatized and extends laterally and to some degree superiority to the sphenoidal sinus. Onodi cell was detected in 210 cases (70%) (Fig. 26). In normal subjects, the uncinate process (UP) appeared as a thin sickle shaped bony leaflet and its concave free margin was parallel to the anterior surface of the ethmoid bulla. Hypoplasia of UP was detected in 72 cases (24%) (Fig.27). Elongation and apparent fusion of the UP tip to the floor of the ethmoid sinus was found in 30 cases (10%) (Fig.28). Pneumatized UP (uncinate bulla) was detected in 24 cases (8%) (Fig.29). Laterally deviated UP was present in 114 cases (38%) (Fig.30), while medial deviation was detected in 84 cases (28%) (Fig.31).

In normal subjects, ethmoid bulla was related laterally to the orbital plate of ethmoid. It extended to the roof of ethmoid and posteriorly to the basal lamella of the middle concha. Enlarged ethmoid bulla was detected in 102 cases (34%) (Fig. 32). Normally, crista galli appeared not pneumatized (Fig.33); its pneumatization was detected in 18 cases (6%) (Figs.34 & 35). Pneumatized middle turbinate (concha bullosa) was encountered in 168 cases (56%) (Figs. 24 & 31). Paradoxically curved middle turbinate with concave medial wall was present in 60 cases (20%) (Fig.36).
### Table 3: Anatomical variations of the sphenoidal air sinus.

<table>
<thead>
<tr>
<th>Variations</th>
<th>No. of cases</th>
<th>Percentage %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unseptated sinus</td>
<td>30</td>
<td>10</td>
</tr>
<tr>
<td>Extensive pneumatization</td>
<td>18</td>
<td>6</td>
</tr>
<tr>
<td>Hypoplasia</td>
<td>12</td>
<td>4</td>
</tr>
<tr>
<td>Bulging of the internal carotid artery into the sinus</td>
<td>150</td>
<td>50</td>
</tr>
<tr>
<td>Impression of the wall of the sinus by the optic nerve</td>
<td>180</td>
<td>60</td>
</tr>
</tbody>
</table>

### Table 4: Anatomical variations of the ethmoid air sinuses.

<table>
<thead>
<tr>
<th>Variations</th>
<th>No. of cases</th>
<th>Percentage %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agger nasi cell</td>
<td>216</td>
<td>72</td>
</tr>
<tr>
<td>Haller's cell</td>
<td>90</td>
<td>30</td>
</tr>
<tr>
<td>Onodi cell</td>
<td>210</td>
<td>70</td>
</tr>
<tr>
<td>Hypoplasia of UP</td>
<td>72</td>
<td>24</td>
</tr>
<tr>
<td>Elongation of UP</td>
<td>30</td>
<td>10</td>
</tr>
<tr>
<td>Pneumatized UP</td>
<td>24</td>
<td>8</td>
</tr>
<tr>
<td>Lateral deviation of UP</td>
<td>114</td>
<td>38</td>
</tr>
<tr>
<td>Medial deviation of UP</td>
<td>84</td>
<td>28</td>
</tr>
<tr>
<td>Enlarged ethmoid bulla</td>
<td>102</td>
<td>34</td>
</tr>
<tr>
<td>Pneumatized crista galli</td>
<td>18</td>
<td>6</td>
</tr>
<tr>
<td>Pneumatized middle turbinate</td>
<td>168</td>
<td>56</td>
</tr>
<tr>
<td>Paradoxically curved middle turbinate</td>
<td>60</td>
<td>20</td>
</tr>
</tbody>
</table>
Fig. (5) : A photograph of coronal CT of paranasal sinuses showing septation of both maxillary sinuses (arrow heads). Note the concha bullosa (C).

Fig. (7) : A photograph of axial CT of paranasal sinuses showing a tooth in the right maxillary sinus (arrow head).

Fig. (6) : A photograph of coronal CT of paranasal sinuses showing left maxillary hypoplasia (H). Note the normal right maxillary sinus (NM).

Fig. (8) : A photograph of coronal CT of paranasal sinuses showing a tooth (arrow) in the right maxillary sinus (M).
Fig. (13): A photograph of coronal CT of paranasal sinuses showing septation of the sphenoidal sinus (arrow head).

Fig. (15): A photograph coronal CT of paranasal sinuses showing extensive pneumatization of the sphenoidal sinus (S) and pneumatization of the pterygoid process (arrow heads).

Fig. (14): A photograph of coronal CT of paranasal sinuses showing unseptated sphenoidal air sinus (arrow).

Fig. (16): A photograph of coronal CT of paranasal sinuses showing sphenoidal sinus hypoplasia (arrows).

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Fig. (21) : A photograph of coronal CT of paranasal sinuses showing unpneumatized agger nasi cells (black arrow). (F) represents the frontal sinus.

Fig. (23) : A photograph of coronal CT of paranasal sinuses showing bilateral enlarged agger nasi cell (arrows). (F) represents the frontal sinus.

Fig. (22) : A photograph of coronal CT of paranasal sinuses showing unilateral agger nasi cell (white arrow). (F) represents the frontal sinus.

Fig. (24) : A photograph of coronal CT of paranasal sinuses showing unilateral Haller's cell (arrow) situated in the medial part of the roof of the right maxillary sinus (M) below the orbit (O). Note the presence of pneumatized middle turbinates (B).
Fig. (29): A photograph of coronal CT of paranasal sinuses showing bilateral uncinate bulla (arrow heads).

Fig. (30): A photograph of coronal CT of paranasal sinuses showing lateral deviation of the uncinate process (arrow). Note the deviated nasal septum (arrow head).

Fig. (31): A photograph of coronal CT of paranasal sinuses showing that the uncinate process is medially deviated (arrow) and attached to the left middle turbinate (M). Note pneumatized right middle turbinate (B).

Fig. (32): A photograph of coronal CT of paranasal sinuses showing well-pneumatized ethmoidal bulla (B). Note the maxillary sinus (M).

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DISCUSSION
The revolutionary changes in the management of sinus diseases in recent years require the clinician and radiologist to have precise and detailed knowledge of the paranasal sinuses anatomy and their anatomical variations; many of which are detectable only by the use of CT (Tonai and Baba, 1996). It is commonly accepted that CT is more useful than the conventional radiology and MRI in delineating anatomical variations of paranasal sinuses because it produces better definition of the bony landmarks (Meyers and Valvassori, 1998). These anatomical variations have been implicated in the etiology of sinusitis and they may also produce difficulties during endoscopic sinus surgery (Lebowitz et al., 2001; Tan and Chong, 2001).

In the present study, different forms of anatomical variations of the paranasal sinuses were detected. Maxillary sinus hypoplasia was detected in 10% of cases. This incidence is almost similar to that reported by Bolger et al. (1991), but is much lower than that reported by Milczuk et al. (1993) and Basak et al. (1998) (17.5% and 20%, respectively). Other investigators (April et al., 1993; Meyers and Valvassori, 1998; Krzeski et al., 2001 and Sirikci et al., 2003) reported lower incidences of maxillary sinus hypoplasia (6.5%, 4%, 2.23% and 4%, respectively). Maxillary sinus hypoplasia should be considered in the differential diagnosis of patients showing an apparently opaque maxillary sinus with plain sinus radiographs to avoid inappropriate treatment (Tonai and Baba, 1996). In the current investigation, the maxillary sinus was divided by septa into unequal cavities in 16% of the cases. This incidence coincides with that reported by Krennmair et al. (1997), but is higher than that reported by Krzeski et al. (2001) and Sirikci et al. (2003) (5.73% and 10%, respectively). Marked projection of a tooth in the floor of the maxillary sinus was detected in 4% of the cases of the present series. This condition may be associated with developmental disturbance, pathological process or iatrogenic activities (Delbalso, 1990).

In this investigation, frontal sinus aplasia was detected in the 4% of the cases. This incidence is lower than
prevalence of Agger nasi cell varied widely among investigators. In anatomic dissections, Agger nasi cell was reported in 10% of the specimens dissected by Messerklinger (1967). Using coronal CT imaging, the incidences of Agger nasi cell reported by Bolger et al. (1991); Lloyd et al. (1991); Kosling et al. (1993); Tonai and Baba (1996); Kayalioglu et al. (2000) and Liu et al. (2002) were 98.5%, 3%, 23.6%, 88.9%, 4.88% and 0.70%, respectively. Differences in reported prevalence of Agger nasi cell could be attributed to the method of analysis employed. The location of Agger nasi is of clinical importance. Its intimate relation to the lacrimal bone and the frontal sinus could be an important factor in infection of lacrimal system and in frontal sinusitis (Mackay and Lund, 1997). Haller's cell was found in 30 % of the cases of the present series. The reported incidences of Haller's cell using CT scanning by Bolger et al. (1991), Tonai and Baba (1996), Stackpole and Edelstein (1997), Sanchez et al. (2000) and Liu et al., (2002) were 45.1%, 33.3%, 34.1%, 3.2% and 1.0%, respectively. Sanchez et al. (2000) attributed the discrepancy in incidences of the prevalence of Haller's cell to variations in interpretation of Haller's cell, sample study or technique of CT scanning. Haller's cell has been implicated as a possible etiological factor in maxillary sinusitis as it can produce narrowing of the maxillary infundibulum (Zinreich et al., 1987; Stammberger and Wolf, 1988). Onodi cell was identified in 70% of the present cases, an incidence which is higher than that reported in previous studies. Habal et al. (1976) using transorbital dissection detected Onodi cell in 25% of the cases. Kainz and Stammberger (1992) using endoscopic dissection reported 42% of the cases with Onodi cell. According to Kusling et al. (1993); Dessi et al. (1994); Sethi et al. (1995) and Sanchez et al. (2000), the reported incidences of Onodi cell using CT scanning were 1.3%, 8%, 3% and 8.3%, respectively. On the other hand, Meyers and Valvassori (1998) detected no Onodi cell in their series.

Uncinate process (UP) was observed in all the present cases. Lang (1989) reported absence of UP in 1% of cases. Elongation of UP was found
ski et al. (2001) stated that an abnormally large middle turbinate may obstruct the ostiomeatal complex causing secondary infection of the ethmoid, frontal and maxillary sinuses. Obstruction of drainage of the concha bullosa itself can lead to mucocele formation.

Paradoxically curved middle turbinate was observed in 20% of the present cases. Bolger et al. (1991); Earwaker (1993); Tonai and Baba (1996) and Basic et al. (1998) reported higher incidences (26.1%, 25%, 29.8%, and 24.2%, respectively). Lower incidences were reported by Calhoun et al. (1991), Lloyd et al. (1991), Kosling et al. (1993), Krzeski et al. (2001) and Sirikci et al. (2003) (12%, 15%, 13.3%, 6.05% and 10%, respectively). Variations in the reported prevalence of the paradoxically curved middle turbinate might be due to the fact that some investigators were concerned only with the paradoxical curve affecting the middle meatus. Paradoxically curved middle turbinate may block the entrance to the middle meatus, however, it has not been reported to be related to sinus disease (Sukalaya and Busakorn, 2005).

In conclusion, the discrepancy in the prevalence of the anatomical variations of the paranasal sinuses detected in the present study and those reported by others may be explained by differences in study population, criteria for the variations or sensitivity of the utilized techniques. The variations reported in the present investigation may be considered as a sample for the Egyptian population and should be taken into consideration when treating or performing operations of paranasal sinuses in the Egyptians.

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