

# Frontal Sinus Drainage in Thai Adult Skulls

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**Objective:** To study the pattern of the nasofrontal drainage in relation to the neighboring anatomical structures in adult Thai cadavers.

**Material and Method:** The anterior aspect of the frontal bone of the embalmed half-head was drilled to identify the presence of the frontal sinus i.e. 40 from only one side of each cadaver were chosen. A silicone base and catalyst were combined then injected into the frontal sinus, which flowed into the nasal cavity through its natural ostium, thereby creating a cast of the nasofrontal connection(s). After allowing five minutes for the silicone to set, the total vertical lamella of the middle turbinate was removed, so the cast could be measured, the connections meticulously dissected and the surrounding structures observed.

**Results:** The investigation revealed five patterns of nasofrontal drainage. The most (60%) common pathway was directly through the frontal recess, while the other pathways 12.5, 10, 10 and 7.5 percent were drained directly into the ethmoid infundibulum, through the agger nasi cell and then into the ethmoid infundibulum, into both the agger nasi cell, the ethmoid infundibulum and the suprabullar recess, respectively. The average sizes of the anteroposterior and mediolateral diameters of the frontal sinus ostium were 6.5 and 5.5 mm, respectively. The agger nasi cell was present in every cadaver with a frontal sinus and was always superior to the ventral attachment of the middle turbinate.

**Conclusion:** The agger nasi cell is the key structure vis-a-vis planning and performing frontal sinus surgery. In preparation for endoscopic intranasal frontal sinus surgery, it is practical to extend the infundibulotomy superiorly into the agger nasi cell, then remove its medial, posterior and superior wall.

**Keywords:** Frontal sinus drainage, Nasofrontal drainage pathway, Frontal sinus surgery, Endoscopic sinus surgery, Agger nasi cell

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Frontal functional endoscopic sinus surgery (FESS) is regarded as the most technically difficult operation among sinus surgeries. In 1989, Kuhn et al<sup>(1)</sup> showed that the most common site for the recurrence of sinusitis was the frontal recess. In 1994, Franzen et al<sup>(2)</sup> demonstrated that there were no improvements in the preoperative and postoperative CT scores of the frontal sinusitis, in contrast to other sinuses.

According to the concepts of FESS, it is essential to establish adequate drainage and ventilation of the frontal sinus through its natural drainage pathway because the small areas of the nasofrontal drainage and the important nearby surrounding structures (i.e. the skull base, the lamina papyracea, and the anterior ethmoid artery) make frontal FESS technically difficult. It is, therefore, necessary that a

precise atlas be prepared of the frontoethmoid anatomy indicating landmarks for the safety and success of frontal FESS.

Relatedly, Kasper<sup>(3)</sup> and van Alyea<sup>(4)</sup> published reports on the drainage of frontal sinus and documented the connection(s) of the frontal mostly via the frontal recess, 60% and 55%, respectively; however these studies were done on Caucasians.

The present study therefore investigated the patterns of frontal sinus drainage and/or the nasofrontal connection in adult Thai skulls, as well as the size of the frontal sinus ostium; the size, connections and relationship with the middle turbinate of the agger nasi cell, pattern of attachment of the bulla lamella and the position of the anterior ethmoid artery in relation to the bulla lamella.

## Material and Method

This was a descriptive study conducted at the Departments of Otolaryngology and Anatomy at the Faculty of Medicine, Khon Kaen University, Thailand. The anterior aspect of the frontal bone of

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each embalmed half-head was drilled to detect the presence of a frontal sinus. Those more than 15 years old at death, with no history of nasal/paranasal sinus surgery/diseases and intact paranasal sinuses, were included in the present study. The authors included 40 half-heads (from one side of each cadaver head) with a demonstrated frontal sinus.

A silicone based compound was mixed with a catalyst and injected into the frontal sinus. The mixture flowed into the nasal cavity through the natural ostium creating a cast of the nasofrontal connection, after allowing five minutes for the silicone to set. The total vertical lamella of the middle turbinate was then removed. The connections along the silicone cast were meticulously dissected and the surrounding structures documented. The cast was removed and measured the narrowest portion corresponding to the true natural ostium of the frontal sinus. Any attachment (s) of the superior extension to the ethmoid bulla (bulla lamella) were noted. The medial wall of the agger nasi cell was meticulously drilled then its dimensions measured and its connections with other spaces explored.

Descriptive statistics were used to characterize the outcome of the: patterns of frontal sinus drainage, patterns of the agger nasi cell connections and attachment of bulla lamella. The continuous outcomes, sizes of the frontal sinus ostium and agger nasi cell, were tested for normality using the Shapiro-Wilk test. If the data had a normal distribution, the mean and 95% confidence interval (CI) were reported. If the data was not distributed normally, the median was stated (*i.e.* the 25 and 75 percentiles).

The Ethics Committee of Khon Kaen University reviewed and approved the study protocols.

## Results

The age at decease of the specimens ranged between 18 and 92 (average, 59.6). Twenty-nine specimens were from males and twenty-one of the total specimens were from the left side of the head.

Five patterns of the frontal sinus drainage were observed (Table 1, Fig. 1). The most common pattern was directly through the frontal recess (24/40 specimens; 60%). Among this pattern, drainage was medial to more than posterior to the agger nasi cell. Other patterns included directly through the ethmoid infundibulum, through both the agger nasi cell and the ethmoid infundibulum, through the agger nasi cell then down to the ethmoid infundibulum. The least common pattern was through the suprabullar recess.

The anteroposterior (AP) and medio-lateral

(ML) diameters of the frontal sinus ostium ranged between 2 and 10 mm (average, 5.5; 95% CI 4.8-6.4) and 2 and 11 mm (average, 6.1; 95% CI 5.5-6.9), respectively.

The agger nasi cell was present in every cadaver. It was situated superior to the ventral attachment of the middle turbinate or anterosuperior to the uncinate process. Its roof was the floor of the frontal sinus. Most of its anterior wall (23 specimens; average, 59.1%) was situated in the same frontal plane as the ventral attachment of the middle turbinate while 37.5% (15 specimens) were found anterior to the ventral attachment of the middle turbinate and the rest (2 specimens; 5%) were behind.

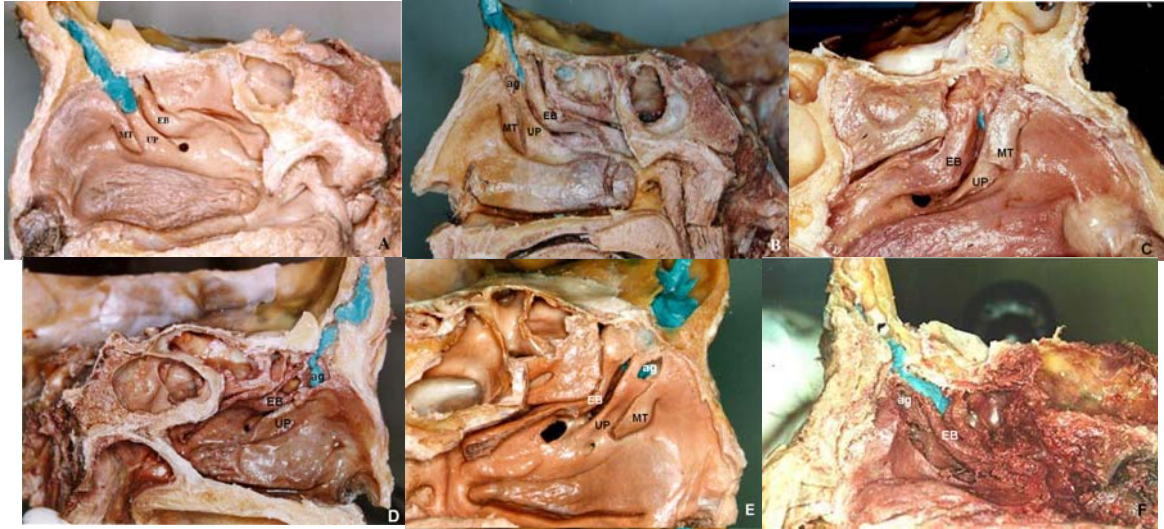
The farthest from the anterior of the agger nasi cell wall to the attachment of the turbinate was 6 mm. The AP, ML and supero-inferior diameters of this cell were between 1-10 mm (average, 5.9 mm; 95% CI 5.3-6.5 mm), 3-10 mm (median, 6; 25% & 75%-ile 5 & 7 mm), 1-13 mm (average, 5.9 mm; 95% CI 5.2-6.6 mm). The most common space connected with the agger nasi cell was the ethmoid infundibulum, 35 specimens (87.5%, 95% CI 73.2-95.8%), followed by the frontal recess, 4 specimens (10%, 95% CI 2.8-23.7%) and the suprabullar recess, 1 specimen (2.5%, 95% CI 0.06-13.2%), respectively.

The anterior wall of the ethmoid bulla extended superiorly as a bulla lamella and mostly attached to the base of the skull, 37 specimens (92.5%, 95% CI 79.6-98.4%) and corresponded to the most anterior aspect of the lateral lamella of the cribriform plate, should be blending with the posterior wall of the frontal sinus. In three specimens the bulla lamella attached the posterosuperior wall of the agger nasi cell creating a connection with the frontal sinus to the suprabullar recess (Fig. 1). The anterior ethmoid arteries ran behind the bulla lamella in all of the specimens.

## Discussion

Frontal endoscopic sinus surgery is the most challenging among the endoscopic sinus surgeries<sup>(2,5-9)</sup>. Many endoscopic sinus surgeons, especially beginners, are not accustomed to the small frontoethmoidal region and are therefore reluctant to perform frontal FESS as they are rightly concerned about complications that may occur from the a complex and variable anatomy of this area.

The present study demonstrated that the most common (60%) pathway for frontal sinus drainage was directly through the frontal recess. This prevalence was comparable to Kasper's and van Alyea's studies (60% and 56%, respectively)<sup>(3,4)</sup>. In the present study,



**Fig. 1** Patterns of frontal sinus drainage. [Color figure can be viewed in the online issue, which is available at [www.mat.or.th/journal](http://www.mat.or.th/journal).]

- A. Directly through frontal recess, medial to agger nasi cell
- B. Directly through frontal recess, posterior to agger nasi cell
- C. Directly through ethmoid infundibulum
- D. Through agger nasi cell and then into ethmoid infundibulum
- E. Through both agger nasi cell and ethmoid infundibulum
- F. Through suprabullar recess

(vertical lamella of middle turbinate was removed in specimens A, B, C, D, E and F, vertical lamella of superior turbinate was removed in specimens B, D and F and in specimen E vertical lamella of supreme turbinate was also removed) (EB = ethmoid bulla, MT = remnant of middle turbinate, UP = uncinat process, ag = agger nasi cell)

the connection directly into the ethmoid infundibulum occurred less frequently, but connections through the agger nasi cell downward into the ethmoid infundibulum and double connections (through both agger nasi cell and ethmoid infundibulum) were not mentioned in the literature although frequent (*i.e.* 10% each). The present study method to identify the pattern(s) of frontal sinus drainage differed from previous studies, which used the cannula to demonstrate nasofrontal connections whereas the authors used a casting material that flowed into the connection. Lee et al studied the frontal sinus outflow tract in 41 cadaver heads (82 frontal sinuses) and demonstrated that the frontal sinus drained anterior to the uncinat process (medial to agger nasi cell) in 24 specimens (29.3%) which was less than our study (37.5%)<sup>(10)</sup>. However a CT study of frontal sinus drainage in Chinese by Bing et al showed higher prevalence, 48.2% (203/421 sides) drained medially to the agger nasi cell and 51.8% (218/421 sides) drained into ethmoidal infundibulum and then to middle meatus<sup>(11)</sup>.

The size of the frontal sinus ostium is one of the important elements of endoscopic surgery, but

there are rarely reports of the size of the frontal sinus ostium in the literature. The AP and ML diameters in our specimen ranged between 2 and 10 mm (average, 5.5; 95% CI 4.8-6.4) and 2 and 11 (average, 6.1; 95% CI 5.5-6.9), respectively, which are larger than those of the Caucasians mentioned in Anon's textbook<sup>(12)</sup> whose ranged from the slit to 7 x 8 mm.

The agger nasi cell was a constant anterior ethmoid air cell as mentioned by Van Alyea<sup>(3)</sup>. Similarly, Bolger<sup>(13)</sup> observed it in 98.6% of cases using CT regardless of the presence of the frontal sinus. The present study confirmed the observation, as this cell was usually situated superior to the ventral attachment of the middle turbinate and anterosuperior to the uncinat process, forming the floor of the frontal sinus. The extent of pneumatization varied and its posterior wall may abut the bulla lamella posteriorly. But, when the agger nasi cell is high and deeply pneumatized, the cell may be mistaken for the frontal sinus during frontal FESS<sup>(14)</sup>, so a pre-operative CT scan is essential and should be reviewed carefully.

The anterior ethmoid artery is an important structures to be aware of during FESS. It stays between

**Table 1.** Patterns of frontal sinus drainage (NM = not mentioned)

Pattern	Kasper <sup>(3)</sup> (n = 100) n (%)	van Alyea <sup>(4)</sup> (n = 112) n (%)	Our study (n = 40)	
			n (%)	95% CI
Directly into frontal recess	60 (60)	(56)	24 (60)	43.3-75.1
Medial to agger nasi cell	NM	NM	15 (37.5)	22.7-54.2
Posterior to agger nasi cell	NM	NM	9 (22.5)	10.8-38.5
Through ethmoid infundibulum	38 (38)	(41.1)	13 (32.5)	18.6-49.1
Directly into ethmoid infundibulum	NM	NM	5 (12.5)	4.2-26.8
Through agger nasi cell and then into ethmoid infundibulum	NM	NM	4 (10)	2.8-23.7
Through both agger nasi cell and ethmoid infundibulum	NM	NM	4 (10)	2.8-23.7
Suprabullar recess	2 (2)	(2.5)	3 (7.5)	1.6-20.4

the bulla lamella and the vertical ground lamella of the middle turbinate. Injury to this artery may cause catastrophic orbital complications such as blindness so the surgeon needs to avoid damaging it. The position of this artery is mentioned in the literature and textbooks<sup>(15)</sup> 1-2 mm behind the bulla lamella. In our study we also found that this artery always stayed behind the bulla lamella, which usually blends with the posterior wall of the frontal sinus and is a very useful landmark in frontal FESS because if the procedure stays in front of this lamella, injury to the anterior ethmoid artery and base of the skull is avoided.

### Conclusion

It is prudent to enter into the agger nasai cell by extending the uncinectomy incision superiorly into the agger nasi cell, when performing frontal FESS. Then the surgeon should remove the medial wall, roof and posterior walls of the agger nasi cell in order to establish wide ventilation and drainage of the frontal sinus. The bulla lamella and the superior aspect of the vertical ground lamella of the middle turbinate are useful landmarks for identification of the anterior ethmoid arteries in Asian patients.

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### Potential conflicts of interest

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## ทางระบายของไซนัสพรอนทัลในกะโหลกศีรษะคนไทยผู้ใหญ่

สงวนศักดิ์ ธนาวิรัตน์านิจ, ภัทรวุฒิ วัฒนศัพท์, โกวิท ไชยศิริวามงคล

**วัตถุประสงค์:** เพื่อศึกษารูปแบบทางระบายของไซนัสพรอนทัลเข้าสู่โพรงจมูกในกะโหลกศีรษะคนไทยผู้ใหญ่  
**วัสดุและวิธีการ:** กรอผนังด้านหน้าของกระดูกไซนัสพรอนทัลในกะโหลกศีรษะครึ่งซีกเพื่อเข้าสู่ภายในโพรงไซนัส โดยใช้กะโหลกศีรษะจำนวน 40 อัน แต่ศึกษาเพียงข้างเดียวของแต่ละกะโหลก ผสมซิลิโคนและตัวเร่งปฏิกิริยาเพื่อทำให้ซิลิโคนเหลว หลังจากนั้นจึงฉีดเข้าไปในไซนัสพรอนทัลที่เจาะไว้ซึ่งสารซิลิโคนจะไหลเข้าไปในโพรงจมูกผ่านทางรูเปิดโดยธรรมชาติ และหลอมทางติดต่อระหว่างไซนัสพรอนทัลกับ โพรงจมูก รอบประมาณ 5 นาที ซิลิโคนที่ผสมจะแข็งตัว หลังจากนั้นทำการตัดเอาส่วนด้านในของ middle turbinate ออก แล้วทำการเอาซิลิโคนที่แข็งตัวออกด้วยความระมัดระวัง วัดขนาดของซิลิโคนส่วนที่แคบที่สุดซึ่งเป็นส่วนของรูเปิด โดยธรรมชาติ พร้อมกับบันทึกอวัยวะที่อยู่โดยรอบของซิลิโคน

**ผลการศึกษา:** สามารถแบ่งทางระบายของไซนัสพรอนทัลได้เป็น 5 รูปแบบ แบบที่พบมากที่สุด (ร้อยละ 60) ได้แก่ การระบายเข้าสู่ frontal recess โดยตรงทางระบายอื่นๆ ได้แก่ระบายเข้าสู่ ethmoid infundibulum โดยตรง, ผ่าน agger nasi cell แล้วเข้าสู่ ethmoid infundibulum, เข้าสู่ทั้ง agger nasi cell และ ethmoid infundibulum และเข้าสู่ suprabullar recess ร้อยละ 12.5, 10, 10 และ 7.5 ตามลำดับ ขนาดเฉลี่ยของรูเปิดของไซนัสพรอนทัลวัดทางด้านหน้า-ด้านหลัง และทางด้านนอก-ด้านในเท่ากับ 6.5 และ 5.5 มิลลิเมตร ตามลำดับ พบมี agger nasi cell ในทุกกะโหลกศีรษะและอยู่เหนือต่อที่เกาะทางส่วนหน้าของ middle meatus

**สรุป:** Agger nasi cell เป็นโครงสร้างหลักในการผ่าตัดไซนัสพรอนทัล เพราะมีความสัมพันธ์กับทางระบายของไซนัส ในการทำการผ่าตัดไซนัสด้วยวิธีส่งกล้องผ่านทางโพรงจมูก จะต้องทำการขยายการตัด uncinat process หรือที่เรียกว่า infundibulotomy ไปทางด้านบนเพื่อเข้าสู่ agger nasi cell แล้วเอาผนังด้านใน ด้านหลังและด้านบนของ agger nasi cell ออก