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Radiological and clinical correlations of the anterior ethmoidal artery in functional endoscopic sinus surgery

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Main Article

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Abstract

Objectives. To correlate computed tomography findings and endoscopic localisation of the anterior ethmoidal artery during surgery, and to analyse the intranasal landmarks and abnormalities of the artery.

Method. The anterior ethmoidal artery was studied with high-resolution computed tomography and endoscopic surgery in 30 patients undergoing functional endoscopic sinus surgery (group A), and with endoscopic dissection on 30 human cadavers (group B).

Results. The anterior ethmoidal artery was demonstrated on computed tomography in 25 patients and intra-operatively in 12 (group A). It was identified in 26 cadavers (group B). Dehiscence of bony canal and branching was noted in 10.53 per cent of cases. The mean (± standard deviation) intranasal length of the anterior ethmoidal artery was 7.29 (± 1.21) mm, the distance of the artery from the axilla of the middle turbinate was 16.24 (± 2.75) mm, and the mean distance from the ground lamella was 8.97 (± 1.46) mm.

Conclusion. High-resolution computed tomography scanning prior to functional endoscopic sinus surgery is mandatory to identify the anterior ethmoidal artery. Endoscopically, the axilla of the middle turbinate and the ground lamella can serve as dependable reference points to identify the artery. Cadaver dissection improves understanding of anatomy.

Introduction

Functional endoscopic sinus surgery (FESS) has evolved to be the surgical treatment of choice for chronic rhinosinusitis with or without nasal polyposis, refractory to maximal medical therapy. The understanding and management of paranasal sinus inflammatory diseases have undergone tremendous modifications since the discourses of Messerklinger and colleagues in the late 1970s.[1] Detailed knowledge of the endoscopic anatomy of the nose and paranasal sinuses can pave the way for safe and accurate surgery. Cadaveric dissection is the only way to become familiarised with the highly variable anatomy. In addition, preoperative computed tomography (CT) scan can minimise the complications of FESS.

Orbital complications after FESS are not uncommon because of the close proximity of the ethmoid sinus to the orbit. The lamina papyracea, a paper-thin bone that separates the ethmoid sinus from the orbit, can be easily breached during such surgery. The anterior ethmoidal artery is an important landmark for locating the frontal sinus and skull base.[2] Therefore, understanding the endoscopic location of the anterior ethmoidal artery and its anatomical variations is critical during FESS or anterior skull base procedures. This not only helps to achieve a satisfactory surgical outcome, but also prevents serious complications during endoscopic procedures. Anterior ethmoidal artery injury during endoscopic procedures can lead to severe bleeding, orbital haematoma or intracranial haemorrhage. Injury to the lateral lamella of the cribriform plate in such situations may also lead to cerebrospinal fluid (CSF) leak.

Accidental injury to the anterior ethmoidal artery should be avoided to prevent such disastrous consequences. The vessel can be coagulated or even ligated via an external (medial canthal) approach or, in the rare occasion where the bony anatomy permits, endoscopically (trans-ethmoidal).[3]

A CT scan is considered the roadmap for FESS. It helps not only to map the extent of sinonasal diseases, but also to identify the variations of paranasal sinus anatomy in each individual. The coronal plane, in particular, is most helpful for assessing the anatomy.

The anterior ethmoidal artery is seen as a classical beaking, also known as a 'Kennedy nipple',[4] 2–3 mm behind the bulla on the medial orbital wall. The artery may lie close to the skull base, or may cross low within the anterior ethmoids, in which case the orbitocranial canal with its bony mesentery is clearly seen. The anatomy significantly varies even between the two sides of the same individual; this may alert the surgeon to areas of potential complications in nasal endoscopic surgery.[5]

The nasal beak, the nasal crest and the axilla of the middle turbinate are useful endoscopic landmarks in relation to the anterior ethmoidal artery that are encountered while operating for FESS and skull base surgery.[6]

We conducted this study to identify the anterior ethmoidal artery in CT scans of patients undergoing FESS and to correlate the CT findings intra-operatively. Endoscopic dissection of cadavers was also performed to check for the location of the anterior ethmoidal artery and the presence of any deviations from normal anatomy.

The study aims were: (1) to correlate the anatomical position of the anterior ethmoidal artery in FESS with respect to pre-operative CT scans; (2) to identify fixed endonasal anatomical landmarks and their distance from the artery; and (3) to categorise the variations of the anterior ethmoidal artery in terms of its course and branching.

Materials and methods

This study was conducted at the Department of ENT and Head Neck Surgery, Vivekananda Institute of Medical Sciences, a tertiary care teaching hospital at Kolkata, West Bengal, India.

Prior approval to conduct this study was obtained from the institutional ethical and scientific committee.

The study comprised two groups; group A consisted of 30 adult patients who underwent FESS, and group B consisted of 30 formalinised cadaver heads on which endoscopic dissection was carried out.

The inclusion criteria for group A were as follows: patients aged over 18 years who were undergoing FESS for chronic rhinosinusitis with or without nasal polyps. Patients were excluded if they were undergoing revision surgery, required surgery for nasal tumours, were a post-irradiation head, neck or face cancer patient, and or did not consent to take part in the study.

All 30 patients in group A gave their informed consent to undergo the surgical procedure and to participate in the study. High-resolution CT (1 mm sections) of the nose and paranasal sinuses was performed for all these 30 patients prior to surgery in order to identify whether anterior ethmoidal artery beaking was present or not. A Siemens Somatom® Emotion CT scanner and OsiriX™ image processing software were used. The CT findings were corroborated with the peri-operative findings: localisation of anterior ethmoidal artery, presence or absence of any dehiscence or branching of anterior ethmoidal artery, and presence of the middle ethmoid artery. The distances of the anterior ethmoidal artery from the anterior face of the middle turbinate axilla and the centre of the ground lamella were measured with the help of a specially designed measuring instrument.

For group B, endoscopic dissection of the anterior ethmoidal artery was performed on 30 human cadaver heads to identify the anterior ethmoidal artery or any of its variations (dehiscence or branching). The dissection was carried out on the side where the nasal cavity was roomy and allowed easy instrumentation. The distances of the anterior ethmoidal artery from the anterior face of the middle turbinate axilla and the centre of the ground lamella were measured, as in the live surgical procedures.

Categorical variables were expressed as number and percentage of patients; these were compared between the two groups using Pearson's chi-square test for independence of attributes. Continuous variables were expressed as mean ± standard deviation (SD), and were compared between the two groups using the Mann–Whitney U test. The statistical software SPSS® version 20 was used for the analysis.

An alpha level of 5 per cent was taken (i.e. p-values lower than 0.05 were considered significant).

Results

A total of 30 patients, ranging from 18 to 68 years of age, with a mean age of 39.63 years, underwent FESS (group A). Of these patients, 14 (46.7 per cent) were female and 16 (53.3 per cent) were male. In the pre-operative CT scan, the beak of the anterior ethmoidal artery, also known as the Kennedy nipple, was identified in 25 cases (83.3 per cent). It was not visualised in the remaining five cases (16.7 per cent).

Of these 25 patients in group A, the anterior ethmoidal artery was identified peri-operatively in 12 patients, whereas the artery was identified only in CT but could not be visualised during FESS in 13 patients. There were five cases in which it was not seen on the CT scan or during FESS. The correlation between the anterior ethmoidal artery seen in FESS and on pre-operative CT scans was significant ($p = 0.046$). In group B, where 30 cadaver heads were dissected, the anterior ethmoidal artery was seen in 26 heads (86.67 per cent).

Of the total 60 samples (groups A and B together), the anterior ethmoidal artery was identified during surgery or dissection in 38 cases (63.33 per cent), but could not be visualised in 22 cases (36.67 per cent).

Dehiscence of the bony canal was found in 4 out of 38 cases (10.53 per cent) and branching was present in 4 cases (10.53 per cent). The middle ethmoid artery was identified in one case only.

In group A, the mean (± SD) intranasal length of the anterior ethmoidal artery was 7.42 (± 1.08) mm. The mean distance of the centre of the anterior ethmoidal artery from the anterior face of the axilla of the middle turbinate was 15.25 (± 2.34) mm. The mean distance of the centre of the anterior ethmoidal artery from the centre of the ground lamella of the middle turbinate was 8.50 (± 1.24) mm.

In group B, the mean (± SD) intranasal length of the anterior ethmoidal artery was 7.23 (± 1.27) mm. The mean distance from the centre of the anterior ethmoidal artery to the anterior face of the axilla of the middle turbinate was 16.69 (± 2.84) mm. The mean distance from the centre of the anterior ethmoidal artery to the centre of the ground lamella was 9.19 (± 1.52) mm.

Finally, out of the total 38 samples where the artery was identified, the mean (± SD) intranasal length of the anterior ethmoidal artery was 7.29 (± 1.21) mm, the mean distance of the artery from the axilla of the middle turbinate was 16.24 (± 2.75) mm and the mean distance from the ground lamella was 8.97 (± 1.46) mm.

Discussion

Functional endoscopic sinus surgery procedures are a set of minimally invasive techniques in which the ostia of the paranasal sinuses are opened and usually enlarged. The surgery aims to re-establish the mucosal drainage and ventilation of the sinuses. The anterior ethmoidal artery is an important landmark for this kind of surgery.

The anterior ethmoidal artery has a trajectory with multiple anatomical variations. The degree of ethmoidal pneumatisation and Keros grades[7] of the depth of the skull base could be predictive factors for the anterior ethmoidal artery relationship. The artery, the axilla of the middle turbinate and the superomedial edge of the nose are in a straight line, which is a simple and useful reference in FESS. Trauma in this region,

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therefore, may easily lead to dural tears, with subsequent CSF leakage, intracranial bleeding,[8] intra-orbital retraction of the artery, orbital haematoma and even cerebral infections.[9] In our series, we did not have any anterior ethmoidal artery injury or complications while performing FESS.

There are ample variations in the course of the anterior ethmoidal canal in the ethmoid sinus; thus, pre-operative knowledge of the artery's course is essential to avoid such complications, which can be well assessed beforehand with the help of a CT scan.[10]

Pernas *et al.*[6] studied 138 CT scans, and determined that the nasal beak was a good radiological landmark to identify the anterior ethmoidal artery, as it was easy to recognise. Ding *et al.*[11] reported that the bilateral medial notch of the orbit (beak) was seen in 100 per cent of cases on CT angiography scans. Gotwald *et al.*[12] found it in 95 per cent of cases. Souza *et al.*[13] also found the anterior ethmoidal artery beak in 100 per cent of cases on CT scans. Basak *et al.*[14] measured the distance between the inferior turbinate and the artery as 30.05 mm by CT scan. However, the inferior turbinate is not a consistent landmark in all subjects. Therefore, we used the beak as the landmark for identification of the anterior ethmoidal artery on CT scans. In our study, the anterior ethmoidal artery beak was seen in 83.3 per cent of cases.

Lannoy *et al.*[15] performed high-resolution CT scans and dissections in 18 ethmoid sinuses (9 heads) and commented that all anterior ethmoidal arteries were identifiable. The correlation between CT scans and the dissection was very satisfactory. Erdogmus and Govsa[16] dissected 19 cadaver heads for bilateral anterior ethmoidal artery, and observed the anterior ethmoidal artery in 29 of 38 cases (76.3 per cent). In our series, of 30 patients in group A, the anterior ethmoidal artery was identified both on CT scan and peri-operatively in 12 patients, which was a statistically significant correlation. However, in 13 cases, the artery was seen only on the CT scan but could not be identified intra-operatively. There were five cases in which the anterior ethmoidal artery was not seen on the CT scan or in FESS.

In group A, the anterior ethmoidal artery was seen intra-operatively in 12 out of 30 cases (40 per cent), whereas in group B the anterior ethmoidal artery was seen in 26 out of 30 cadaver heads (86.67 per cent). Hence, in a total sample size of 60, the anterior ethmoidal artery was seen in FESS in 38 cases (63.33 per cent) and was not seen in 22 cases (36.67 per cent). The lower rate of visualisation of the anterior ethmoidal artery during surgery compared with cadaver dissection may be attributed to the fact that, in surgery, we do not indulge in unnecessary aggressive dissection to visualise the artery. This echoes the basic conservative principle of FESS.

The anterior ethmoidal artery is usually encased in a bony canal; thus, the likelihood of injury is lower. If the artery is distant from the ethmoid roof, the inferior bony wall of the artery is naturally weak and therefore easily accessible. If not handled with caution during surgery, it is prone to inadvertent injury. Dehiscence in the bony canal was observed in 1 of 12 anterior ethmoidal arteries (8.33 per cent) and in 3 out of 26 heads (11.54 per cent) in groups A and B respectively. Therefore, in a total sample size of 60, anterior ethmoidal canal dehiscence was recorded in 4 of 38 cases (10.53 per cent) where the artery was visualised. Simmen *et al.*[17] observed that the anterior ethmoid canal was dehiscent in 33.3 per cent of the cases, whereas Moon *et al.*[8] observed the dehiscence rate to be 11.4 per cent, which is close to that of the present study.

Lang and Schafer[10] commented that the anterior ethmoidal artery could be unilaterally absent in 14 per cent of cases, bilaterally absent in 2 per cent and multiple in 30 per cent. If the anterior ethmoidal artery is absent, it is replaced by a branch of the posterior ethmoidal artery. Wang *et al.*[18] found the middle ethmoidal artery in 31.8 per cent of cases. In the present study, none of the group A patients had any branching of the anterior ethmoidal artery, whereas in group B branching of the anterior ethmoidal artery was seen in 4 out of 26 arteries (15.38 per cent) that were seen in total. In a total sample size of 60, the anterior ethmoidal artery was seen in 38 cases, of which branching of the anterior ethmoidal artery was found in 4 cases (10.53 per cent). In one of the cadavers, a middle ethmoidal artery could be seen (2.6 per cent). In the present study, the incidence of a middle ethmoidal artery in the Eastern Indian population was much higher when compared with previous studies from other geographical regions of the world.

Araujo *et al.*,[19] from Brazil, observed that the average intranasal length of the anterior ethmoid artery was 5.2 mm. In our study, the mean intranasal length of the anterior ethmoidal artery was 7.42 (± 1.08) mm in group A and 7.23 (± 1.27) mm in group B. Thus, in a total of 38 cases, the mean intranasal length was 7.29 (± 1.21) mm. Again, the intranasal length of the anterior ethmoidal artery is slightly higher in the Eastern Indian population than in studies conducted elsewhere.

Araujo *et al.*[19] also commented that the middle concha axilla is the most reliable point of reference to locate the anterior ethmoidal artery. They reported the average distance between the middle point of the artery and the middle concha axilla to be 21.14 mm. Lee *et al.*[20] dissected 28 cadavers endoscopically and concluded that the median distance between the artery and the anterior face of the axilla of the middle turbinate was 20 mm. Han *et al.*[2] dissected 48 nasal cavities and found that the mean distance of the anterior ethmoidal artery from the axilla was 17.5 mm.

In group A of our study, the mean distance from the centre of the anterior ethmoidal artery to the anterior face of the axilla was 15.25 (± 2.34) mm, whereas in group B it was 16.69 (± 2.84) mm. Thus, in the total 38 anterior ethmoidal arteries identified, the mean distance from the axilla of the middle turbinate was 16.24 (± 2.75) mm. Our findings were similar to those of Han *et al.*[2]

- Computed tomography scanning is necessary prior to functional endoscopic sinus surgery (FESS) for thorough understanding of the anterior ethmoid artery
- The middle turbinate axilla and ground lamella can serve as dependable reference points to identify the artery during surgery
- Variations like artery dehiscence and branching should be considered and identified to avoid complications during FESS

Lannoy *et al.*[15] used the roof of the ethmoid as a landmark, whereas Lisbona *et al.*[21] and Erdogmus and Govsa[16] used the second lamella as the landmark. Lee *et al.*[20] surveyed the distance between the artery and the axilla formed by the lateral nasal wall. The mean distance and angle between the limen nasi and the anterior ethmoidal canal were measured by Moon *et al.*,[8] and by Erdogmus and Govsa.[16] Lund *et al.*[22] suggested the posterior wall of the frontal recess as the reference point for this artery. As the pneumatisation of these structures can vary, we used the centre of the ground lamella as the second fixed bony landmark.

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The mean distance from the centre of the anterior ethmoidal artery to the centre of the ground lamella was 8.50 (± 1.24) mm in group A, whereas in group B it was 9.19 (± 1.52) mm. Thus, in the total 38 cases, the mean distance from the ground lamella was 8.97 (± 1.46) mm. We can use the centre of the ground lamella as one of the fixed landmarks to assess the location of the anterior ethmoidal artery while performing FESS to prevent complications.

Conclusion

A judiciously performed CT scan with proper sections in the correct plane can delineate the anterior ethmoidal artery in the majority of cases. The medial notch of the orbit (beak) is a very dependable parameter for identification of the anterior ethmoidal artery radiologically, and correlates well with intra-operative identification. The intranasal length of the artery is variable. The axilla of the middle turbinate is the most reliable reference point for endoscopic localisation of the anterior ethmoidal artery. The ground lamella of the middle turbinate also serves as an additional and reliable reference point to trace the artery during surgery. Intranasal branching or dehiscence is noted in around one-tenth of individuals. Endoscopic cadaveric dissection of the artery is beneficial in mastering its localisation and recognising its variations, which can pave the way for safe surgery.

Our study opens a new avenue of using the ground lamella as a landmark to locate the anterior ethmoidal artery, because it is fixed and generally has no variations. This has not been discussed in previous studies.

Competing interests. None declared

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