

Original Article

Simultaneous observation and discrimination of palatovaginal and vomerovaginal canals by transverse CT

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Abstract: This study is to palatovaginal canal and vomerovaginal canal identify by computed tomography (CT) transverse imaging and are often mislabeled by investigators. We used a probe guide method in skull specimens to establish the CT imaging features of the two canals. We also used endoscopy to look deeply into the inside structure of them. Finally, CT images of patients were used to confirm our findings. Based on our results using 20 skull specimens and 70 patients, we established a simple method that can be used to identify the two canals on CT transverse imaging. In the transverse images of skull specimens and of patients, the frequency of simultaneous observation of the two canals was 72.5% and 70.71%. We also identified several mislabeled images of the palatovaginal and vomerovaginal canals in published papers. In summary, we found that the two canals could be observed and distinguished by transverse CT imaging. Furthermore, we established a method that could distinguish them. In conclusion, our findings will have a great impact not only on the accurate identification of the pterygoid canals but also on the early detection of tumor metastasis and palatine artery embolization.

Keywords: Palatovaginal canal, pterygoid canal, vomerovaginal canal, CT transverse imaging, pterygopalatine fossa

Introduction

Computed tomography (CT) is a widely used technology that produces tomographic images of specific areas in the axial, coronal, or sagittal planes, allowing the user to see inside the object without cutting [1]. It is especially useful for the diagnosis of tumors at different locations or organs [2]. The pterygopalatine fossa (PPF) is a fossa in the skull that is quite important as it is a neurovascular crossroad of the nasal cavity, masticator space, orbit, oral cavity, and middle crania fossa [3]. It is a cone-shaped paired depression deep into the infratemporal fossa and posterior to the maxilla on each side of the skull [4]. Altogether, the PPF directly communicates with seven different regions via nine passageways. It has five boundaries, including the anterior, posterior, medial, lateral, and inferior boundaries. There

are four passageways in the posterior boundaries, including the foramen rotundum, pterygoid canal, palatovaginal canal, and vomerovaginal canal [5]. Distinguishing the four passage ways by CT imaging has significant clinical value for the diagnosis of various diseases [6].

Each of the four passageways has its unique role, but it is difficult to distinguish each of them by CT imaging or other available technologies [7]. The pterygoid canal runs anteriorly from the anterior border of the foramen lacerum, through the sphenoid sinus floor, and to the end of the pterygopalatine fossa. It holds the pterygoid nerve and artery, and it is important for surgery [8]. The palatovaginal canal is a canal formed by the sphenoidal process of the palatine bone and the vaginal process of the sphenoid bone that connects the nasopharynx with the PPF; thus, it carries the pharyngeal branch of the

third part of the maxillary artery [9]. The posterior opening of the palatovaginal canal becomes a shallow groove and is called the posterior groove hereafter [10]. The vomerovaginal canal is located between the vaginal process of the sphenoid and the ala of the vomer, and it conveys a branch of the sphenopalatine artery [7, 10]. Although several reports have described the palatovaginal canal by CT imaging at the coronal plane, the literature regarding the vomerovaginal canal is very limited.

Nasopharyngeal carcinoma can infiltrate the maxillary nerve and affects the palatovaginal canal, and such infiltration is important as it affects both the prognosis and radiation treatment [11, 12]. Moreover, observation of the palatovaginal canal is also important in the management of resistant posterior epistaxis, especially in posttraumatic cases, and during extended endoscopic procedures [13]. Knowledge regarding the vomerovaginal canal based on CT images is very limited, and sometimes it is mislabeled as the palatovaginal canal [13]. Therefore, we examined whether the palatovaginal canal and vomerovaginal canal can be observed simultaneously in transverse CT images. Furthermore, we distinguished these two canals by transverse CT imaging.

Materials and methods

Samples

This study included 20 skull specimens and 70 patients. The 20 skull specimens were used for establishment of standards to observe the palatovaginal canal and vomerovaginal canal. The 20 skull specimens were scanned by multi-slice spiral computed tomography (MSCT) and nasal endoscopy. The 70 patients were used to examine our established standards obtained from the skull specimens.

Endoscopic and CT imaging of skull specimens

The skull specimens were observed by a physician to rule out potential head and facial trauma as well as a history of surgery. All 20 specimens were normal and were further analyzed by two expert otolaryngologists. The two open ends (towards the PPF and nasopharynx) of palatovaginal canal were determined by two expert otolaryngologists for each specimen.

Aluminum metal probes were inserted from the opening of the nasopharynx to the opening of the PPF. These probes were used to determine the position of the palatovaginal canal in the skull specimens by MSCT. After the first scan, these probes were taken out of the specimen, and the specimens at the same position were scanned again by MSCT. The transverse CT images were analyzed, and the data were used to distinguish the palatovaginal canal and vomerovaginal canal. Two skull specimens were further evaluated by using nasal endoscopy to understand the inside anatomy of the palatovaginal canal and vomerovaginal canal.

All the imaging data were measured by two radiologists. Each value was measured three times, and their average was calculated. In case of disagreement, the two radiologists discussed the results to form a consensus. The frequency of simultaneous observation of both the palatovaginal and vomerovaginal canals was also recorded. As the baseline scan parallel to the hard palate, the angles between the palatovaginal canal and hard palate, between the posterior groove and hard palate, and between the posterior groove and sagittal plane were measured and recorded. (The values were defined as positive for posteromedial angles and negative for posterolateral angles). The angle between the posterior groove and the hard palate was very small. The lower angle between the posterior groove and the hard palate enables the former to be better visualized than the palatovaginal canal itself in the axial sections, which are parallel to the hard palate. Oblique sagittal multiplanar reconstruction (MPR) was used to measure the length of the palatovaginal canal. The angle between the palatovaginal canal and the pterygoid canal was measured and compared with previous reports.

All CT images were produced by using a SOMATOM Definition AS 40-slice CT machine manufactured by Siemens. The scanning parameters were as follows: 120 kV, 200 m as, 512×512 resolution, and a layer thickness and distance of 0.6 mm. The scanning range was from the palate plane to the clinoid level. Coronal reorganization was perpendicular to the hard palate from the posterior wall of the maxillary sinus to the rupture hole. The original data were further analyzed by Syngo CT Workplace to obtain the 3D positioning, MPR,

Table 1. The length and angle of the palatovaginal canal in skull specimens

Parameter	Left side	Right side	T value	P value
Angle to the pterygoid canal (°)	44.27±4.23	43.28±5.04	1.094	0.288
Angle to the palatal plane (°)	53.56±6.23	52.72±4.74	0.508	0.617
Length (mm)	4.24±0.51	4.35±0.61	-1.119	0.246
Angle of the posterior groove to the palatal plane (°)	21.36±6.21	20.52±6.48	0.692	0.497
Angle of the posterior groove to the sagittal plane (°)	2.65±3.271	3.05±3.71	-0.469	0.644

etc. The reorganized thickness layer was 0.6 mm, and the distance between each layer was 0.4 mm. Reconstruction under the bone algorithm showed that the window width was 4000 HU, and the window level was 700 HU.

CT images of patients

The 70 patients were recruited at our hospital between January and June 2014. All the patients were scanned by CT to check the area of the PPF. All patients met the following criteria: (1) older than 18 years of age; (2) had a normal PPF structure. Patients were excluded if the image had artifacts or the patients had experienced trauma. The study was approved by the local hospital ethics committee, and all patients gave written informed consent. All the CT scans and data analysis were performed under the same conditions as those used for the skull specimens.

Statistical analysis

All statistical analyses were performed by using SPSS18.0 software. All numerical data were presented as mean ± standard deviation. The difference between sides was analyzed by using a paired two-sided t-test. The difference between data from skull specimens and patients was analyzed by using the two independent samples T test. $P < 0.05$ was considered statistically significant.

Results

CT imaging of the palatovaginal and vomerovaginal canals of skull specimens

Both of the opening ends towards the PPF and nasopharynx were observed in all 20 skull specimens. All aluminum metal probes entered into the opening ends towards the nasopharynx and came out the opening end towards the PPF between the pterygoid canal. The posterior groove could be identified in all samples at both

sides (40/40; 20 specimens, 2 sides). In the transverse CT images for the probe-containing skull specimens, the probes ran posteriorly towards the inner rear between the pterygoid canal and the vomerovaginal canal. The palatovaginal canal also showed a stable image after removal of the probes in the transverse CT images. The palatovaginal canal located in the interior of the front opening of the pterygoid canal and the overall pattern was towards the posterior and interior borders. Its anterior opening looked like a bell and was positioned towards the anterior and exterior borders. Its middle looked like a slender tube and was concave. Its posterior opening was in contact with the posterior groove, which looked like a long pipe and was approximately parallel to the median sagittal plane. Around the posterior opening, bone-like structures were frequently observed. From front to back, the distance between the pterygoid canal and the vomerovaginal canal increased. On the same transverse CT image, the frequency of simultaneous observation of both the palatovaginal and vomerovaginal canals was 72.5% (29/40). In 11 out of 40 sides (27.5%), the palatovaginal and vomerovaginal canals could not be distinguished. Among the 11 sides, 2 of them were due to over-gasification of the sphenoid. The other nine sides were due to the fact that both the front and back openings of the palatovaginal canal are below the vomerovaginal canal or the connection between the palatovaginal canal and vomerovaginal canal. In 13 sides (32.5%), we observed the bone-like structure between the front opening of the palatovaginal canal and vomerovaginal canal. The bone-like structure was more frequently (29/40; 72.5%) observed at the back opening of the palatovaginal canal and vomerovaginal canal. The length and angle of the pterygoid canal are also listed in **Table 1** (**Table 1** and **Figure 1**).

Two skull specimens, including four sides, were also observed by endoscopy. Under endoscopy,

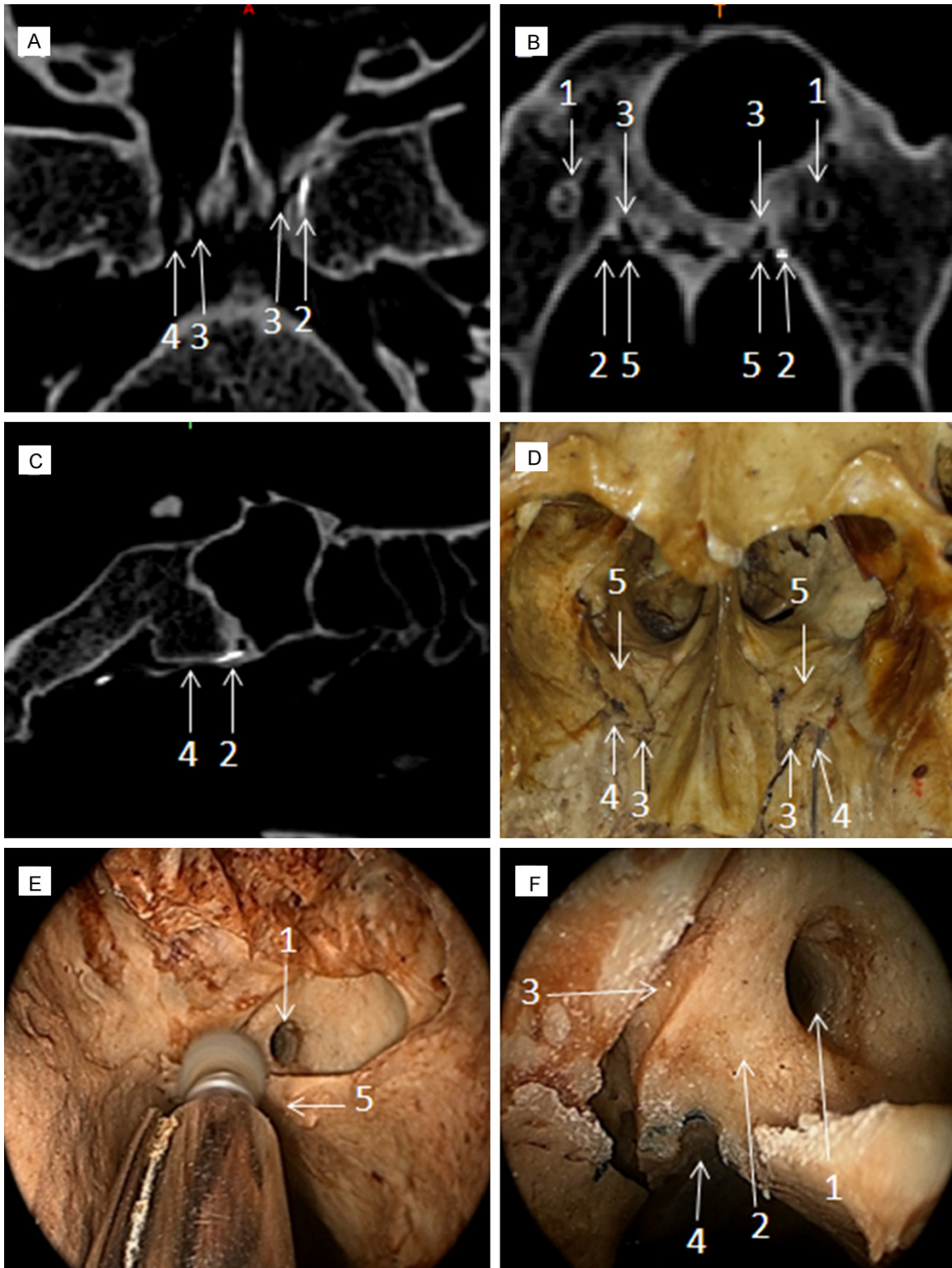


Figure 1. The images of skull specimens with probes. A. A probe was inserted into the left palatovaginal canal and its CT transverse plane. The bone interval between the palatovaginal canal and vomerovaginal canal is also indicated. B. The palatovaginal canal is located inferior and exterior to the vomerovaginal canal by CT coronal imaging. C. In the sagittal plane, the probe goes down with a short length. D. The probe comes from the back opening of the palatovaginal canal and was close to the posterior groove. E. Removal of the left sphenoidal process of the palatine bone by a diamond drill. F. Full view of the left palatovaginal canal and vomerovaginal canal. The posterior groove was deeper than the impression in the inferior surface of the vaginal process caused by the palatovaginal canal. The

Palatovaginal and vomerovaginal canal by CT

vomerovaginal canal was deep and medial to the palatovaginal canal. The blue ink line represents the projection of the posterior border of the sphenoidal process on the vaginal process; 1= pterygoid canal; 2= palatovaginal canal; 3= vomerovaginal canal; 4= posterior groove; 5= sphenoidal process of the palatine bone.

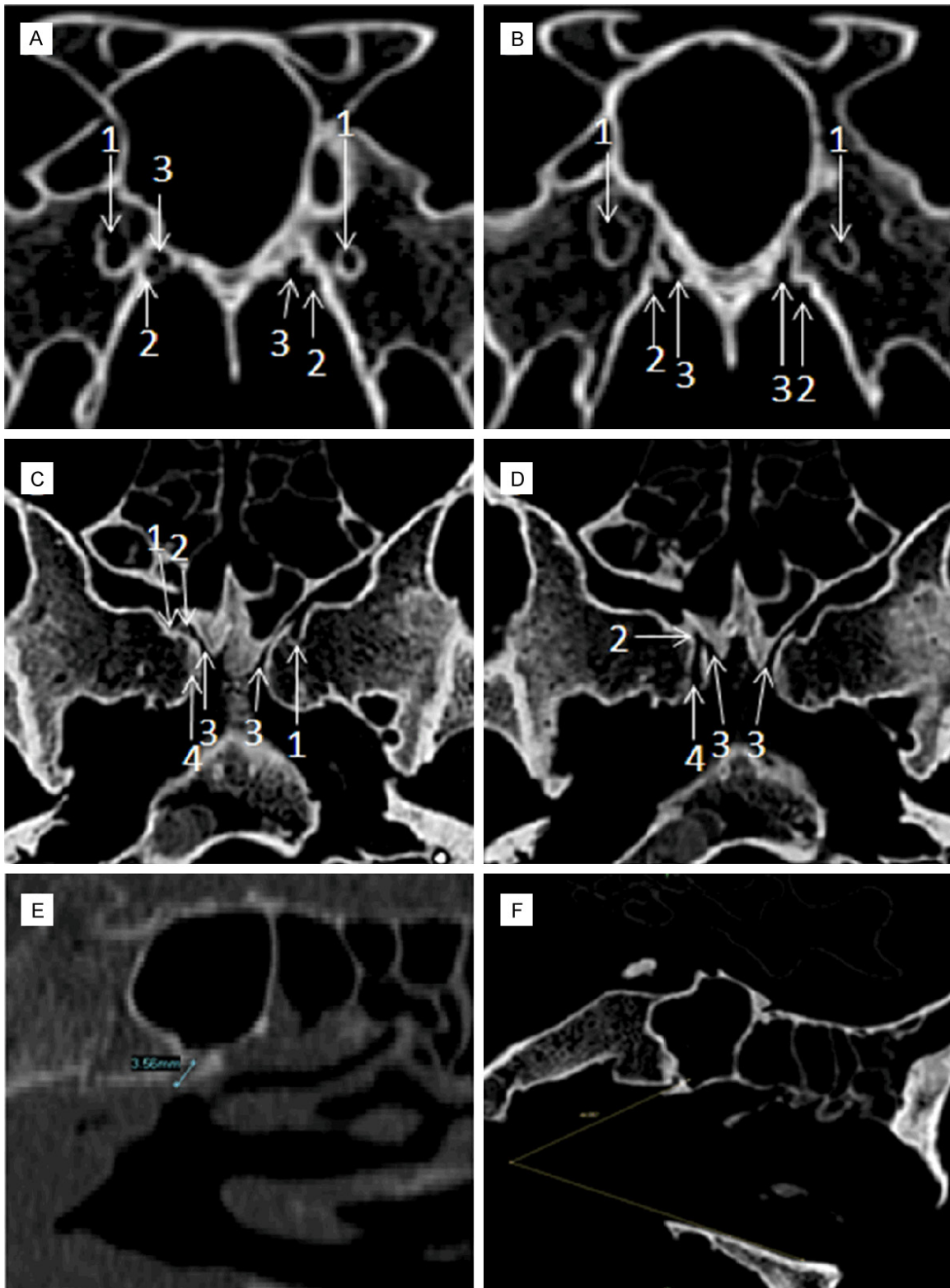


Figure 2. CT images of skull specimens and patients without probes. (A) Coronal multiplanar reconstruction (MPR) at the level of the anterior opening of the palatovaginal canal. The bony septum between the anterior segments of

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the right palatovaginal canal and the vomerovaginal canal was very thin. The vomerovaginal canal was superomedial to the palatovaginal canal. The vidian canal was superior to the palatovaginal and vomerovaginal canals. (B) Coronal MPR at the level of the posterior opening of the palatovaginal canal. The septum between the palatovaginal canal and the vomerovaginal canal at this level was relatively thick. The posterior groove and the vomerovaginal canal were shallow. The vidian canal was superior to the palatovaginal canal. The vomerovaginal canal ran superiorly to the inferior wall of the sphenoidal sinus. (C) The undistinguished palatovaginal canal and vomerovaginal canal on the right side but the full view of the vomerovaginal canal on left side. (D) The back opening of the palatovaginal canal containing the CT slice, which is two slices inferior to the image (C) and shows a bone interval between the palatovaginal canal and vomerovaginal canal. The posterior groove was a long tube nearly parallel to the median line, which should be easily identified. (E) Oblique sagittal MPR of patients for measuring the length of the palatovaginal canal. (F) Sagittal MPR of skull specimens for measuring of the angle between the palatovaginal canal and the hard palate. 1= pterygoid canal; 2= palatovaginal canal; 3= vomerovaginal canal; 4= posterior groove.

Table 2. The length and angle of the palatovaginal canal in patients

Side	Angle to pterygoid canal	Angle to palatal plane	Length	The angle of posterior groove to palatal plane	The angle of posterior groove to sagittal
Left	43.95±5.39	53.52±7.47	4.28±0.75	20.85±5.46	2.02±4.16
Right	43.68±5.02	52.85±6.26	4.41±0.86	20.38±4.84	2.39±4.19
t value	0.579	0.635	1.669	0.915	-0.661
p	0.564	0.528	0.100	0.363	0.511

the pterygoid canal, palatovaginal canal, and vomerovaginal canal appear differently. The pterygoid canal is almost parallel to the sagittal plane and faces the posterior direction. Compared to the pterygoid canal, the palatovaginal canal goes down and is located in the posterior and interior direction. Its back opening is linked to the posterior groove, which often presents as a deeper pressure trace than the palatovaginal canal on the vaginal process. The vomerovaginal canal goes down and is in the inner-posterior direction. The front part shows a big angle with the midline. After the nasopharynx, it goes between the vaginalis and vomer. In this area, its angle to the midline is small. There is a bone interval between the palatovaginal canal and vomerovaginal canal. In the two sides, there is only a bony prominence between them in their anterior parts. The interval between the back opening of the palatovaginal canal and vomerovaginal canal is wide (**Figure 2**).

CT images of patients

Using the CT images from the skull specimens and the detailed endoscopic results, we established the imaging features of the palatovaginal canal and vomerovaginal canal. Based on these findings, we further examined whether we could distinguish these two structures in patients by CT transverse imaging. Consistently, the overall imaging features of the palatovaginal canal and vomerovaginal canal are similar

to those of the specimens. The frequency of simultaneous observation of the palatovaginal and vomerovaginal canals was about 70.71% (99/140). In 41 out of 140 sides (29.29%), the palatovaginal and vomerovaginal canals could not be distinguished. Among these 41 sides, 13 of them had over-gasification of the sphenoid or poor development of the palatovaginal canal and vomerovaginal canal. The other 28 sides were due to the fact that both the front and back openings of the palatovaginal canal were below the vomerovaginal canal or the connection between the palatovaginal canal and vomerovaginal canal. In 34 sides (24.29%), we could observe the bone-like structure between the front opening of the palatovaginal canal and vomerovaginal canal. The bone-like structure was more frequently (97/140; 69.29%) observed at the back opening of the palatovaginal canal and vomerovaginal canal. The length and angle of the pterygoid canal are also listed in **Table 2** (**Table 2** and **Figures 2, 3**). Next, we compared the skull specimen data and the patient data, and there was no significant difference between these two groups (**Table 3**). These findings suggest that the standards established from the specimens are reliable and that the imaging features of the palatovaginal canal and vomerovaginal canal are stable.

Discussion

The PPF contains the pterygopalatine ganglion and various arteries, veins, lymphatics, and

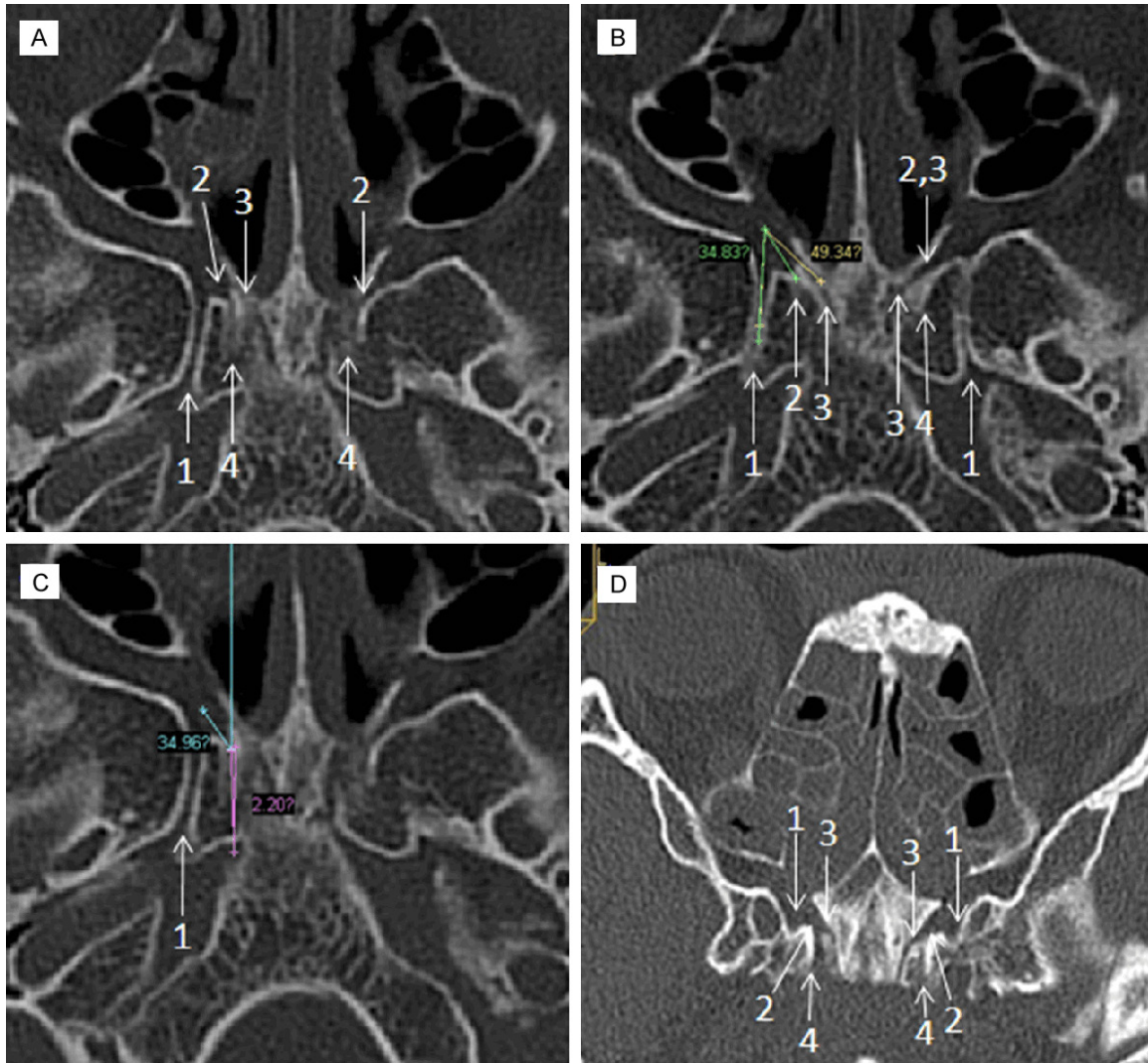


Figure 3. CT imaging of the palatovaginal canal in patients. A. Simultaneous observation of the right pterygoid canal, right palatovaginal canal, and right vomerovaginal canal by transverse CT imaging. B. The angle of the pterygoid canal to the vomerovaginal canal (yellow angle) is larger than the angle of the pterygoid canal to the palatovaginal canal (green angle). C. The angle of the palatovaginal canal to the sagittal plane (blue angle) and the angle of the posterior groove to the sagittal plane (purple angle). The posterior groove was nearly parallel to the median line; D. Oblique axial view of another patient showing the full course of the right palatovaginal canal, the bony septum between the palatovaginal canal and the vomerovaginal canal, and the posterior groove. 1= pterygoid canal; 2= palatovaginal canal; 3= vomerovaginal canal; 4= posterior groove.

nerves (5). It is an important cranial neurovascular crossroad as well as a common site for invasion and perineural spread of malignant disease [14, 15]. The palatovaginal canal and vomerovaginal canal are two important structures posterior to the PPF (14).

The palatovaginal canal is an important landmark for the identification and protection of the vidian nerve [13]. Studies have shown that nasopharyngeal cancer can spread via the palatovaginal canal into the PPF, where it can

potentially disseminate to other locations through other canals of the PPF [11, 16]. Variations in the diameter and course of the arteries can complicate any surgical intervention involving the palatovaginal canal. Therefore, understanding the anatomy of the palatovaginal canal is valuable in such situations because it can help to identify the vidian canal, allow accurate manipulation of coagulation and embolization of the pharyngeal artery, and facilitate early detection of metastatic lesions of nasopharyngeal cancer [11, 13, 17].

Table 3. Comparison of data between specimens and patients

Side	Angle to pterygoid canal	Angle to palatal plane	Length	The angle of posterior groove to palatal plane	The angle of posterior groove to sagittal
Specimens	43.78±4.62	53.14±5.48	4.29±0.56	20.93±6.28	2.85±3.46
Patients	43.81±5.19	53.19±6.87	4.34±0.68	20.31±5.54	2.21±4.16
t value	-0.042	-0.041	-0.382	0.610	0.892
p	0.967	0.967	0.703	0.543	0.373

The vomerovaginal canal is located between the wing of the vomer and the vaginal process of the sphenoid bone. The superior wall of the vomerovaginal canal is formed by the inferior surface of the vaginal process and, sometimes, also by the lateral wall of the vomer wing. The vomerovaginal canal starts from the posterior wall of the PPF (or the vidian canal) and runs posteromedially. The angle between the anterior segment of the vomerovaginal canal and the median line is quite large (means of 48.67° and ranging from 28° to 70°), while the left and right angles between the posterior segment of the vomerovaginal canal and the median line are relatively small (means of 12.07° and ranging from 2° to 25° for the left; means of 14.60° and ranging from 1° to 28° for the right). The vomerovaginal canal contains nerve fibers and arterioles with diameters of several hundred micrometers [7]. Moreover, the anatomy and imaging studies of this canal have rarely been reported.

Although these two structures could be frequently observed and distinguished in the coronal plane by CT imaging, it is believed that these two structures are difficult to be observed and distinguished by transverse CT imaging due to their smallness, shortness, and similar routines [7, 10, 16, 17]. Here, by using probes inserted into the skull specimens, we are the first to establish the CT imaging features of the palatovaginal canal and vomerovaginal canal by transverse CT imaging. We further applied our findings with clinical patients and found that the palatovaginal canal and vomerovaginal canal could be frequently observed simultaneously. Thus, the palatovaginal canal and vomerovaginal canal should be considered differently in the clinic. Our findings will have a great impact not only for the accurate identification of the pterygoid canal, but they also will aid in the early detection of tumor metastasis and palatine artery embolization.

To the best of our knowledge, only a few reports have mentioned the palatovaginal canal and

vomerovaginal canal in transverse CT images [7, 18, 19]. Thus, based on our experience from the skull specimens and patients, we established a simple method to identify the palatovaginal canal and vomerovaginal canal by transverse CT imaging. The first step is to identify the pterygoid canal, whose posterior opening is the rupture hole. The second step is to identify the vomerovaginal canal. It is the most interior and oblique structure, but it has a clear and low density curve close to the lateral edge of the vomer. The third step is to identify the front opening of the palatovaginal canal. It is a backward depression one to two CT slices below the intersection of the pterygoid canal and vomerovaginal canal. The fourth step is to identify the back opening of the palatovaginal canal. It is linked to the posterior groove, which is very close to the lower surface of the sphenoid bone vaginalis and approximately parallel to the sagittal plane. The angle between the posterior groove and the sagittal plane is about 2.85°, while its angle to the hard palate is about 20.93°. Because it has small angle to the hard palate, it is more easily observed by transverse CT imaging compared to the palatovaginal canal and presents as a long and slender backward tube. In our study, the posterior groove could be observed in all cases; therefore, it is a good marker to be used to identify the palatovaginal canal. The palatovaginal canal is located between the back opening and front opening, which is a posterior and interior depression. By using this method, we have successfully and simultaneously identified the palatovaginal and vomerovaginal canals by transverse CT imaging in 29 out of 40 (72.5%) skull specimen sides and in 99 out of 140 (70.71%) patient sides. These findings suggest that our established method is reliable and could be easily applied to clinical practice.

The angle between the palatovaginal canal and pterygoid canal is about 43.78°, while the angle between the palatovaginal canal and hard palatal plane is about 53.14°. These results suggest that the palatovaginal canal goes in the interior and posterior direction. After it goes out

the back opening, it becomes a shallow ditch that is the posterior groove. We found that the length of the palatovaginal canal is only about 4.28 mm and with large angles. Conventional CT imaging of the sinus and PPF area is often parallel to the palatal plane, and it is difficult to be parallel to the long axis of the palatovaginal canal. Thus, it is hard to see the long tubular presentation of the palatovaginal canal, and it most often shows as a depression-like fragment. Therefore, it is easily ignored. Furthermore, its front opening is very close to or even joined with the vomerovaginal canal, so it is also easy to consider the vomerovaginal canal as the palatovaginal canal by default (**Figure 2C**).

Before our current systematic analysis of the palatovaginal and vomerovaginal canals in skull specimens and patients, many clinical doctors, including those in our department, frequently made mistakes in the identification of palatovaginal and vomerovaginal canals. A literature survey indicated that many publications mislabeled the vomerovaginal canal as the palatovaginal canal. For example, in several published CT transverse images, we could identify the front opening of the palatovaginal canal by our established method. However, this structure did not receive the attention of the investigators and, instead, the authors mislabeled the vomerovaginal canal as the palatovaginal canal [13, 18].

In this previous report, the angle between the palatovaginal canal and pterygoid canal is about 48°, which is larger than shown by our data. The length of the palatovaginal canal is about 7.15 mm, which is also much longer than shown by our data. But based on their presentation, we found that the labeled line for the palatovaginal canal is actually the vomerovaginal canal. Therefore, we believe that the angle between the palatovaginal canal and the pterygoid canal is actually the angle between the vomerovaginal canal and the pterygoid canal. Their measured length of the palatovaginal canal is the length of the vomerovaginal canal or the gap between the vomerine and vaginalis [13].

In another publication, researchers have identified the palatovaginal canal by CT transverse imaging, and their image features are similar to ours [7]. However, they mislabeled the posterior groove as the palatovaginal canal. We believe

that this mistake is due to the lack of endoscopy knowledge regarding the palatovaginal canal, vomerovaginal canal, and posterior groove [7]. Based on our current image features as well as our established method, these kinds of mistakes could be avoided.

Unlike by transverse CT imaging, the majority of reported references correctly labeled the palatovaginal canal and vomerovaginal canal in the coronal plane. The reason that is that at the back opening of the vomerovaginal slice, the distance between the pterygoid canal, palatovaginal canal, and vomerovaginal canal is longer and could be distinguished by high-resolution CT scanning. They all showed the presentation of complete or semicanals, including the pterygoid canal, palatovaginal canal, and vomerovaginal canal [13, 16].

Although we established a simple method to identify the palatovaginal canal and vomerovaginal canal by CT transverse imaging, it was still difficult to discriminate these two structures in about 30% of samples. One reason is due to over-gasification of the sphenoid, and another reason is due to variation of the structure in the population or that the two canals have a joined opening. This limitation could be overcome by more CT imaging data regarding the palatovaginal canal and vomerovaginal canal, refinement of computer techniques of medical imaging, and precise studies in a larger series of skulls to describe the anatomy of the palatovaginal canal, the vomerovaginal canal, the posterior groove, and their anatomic relationships.

Conclusion

Our data clearly showed that the palatovaginal canal and vomerovaginal canal could be simultaneously observed and distinguished by transverse CT imaging. The discrimination of these two structures is critical and useful to detect the spread of nasopharyngeal cancer. Furthermore, we also established a method that can be used to distinguish the palatovaginal canal and vomerovaginal canal by CT transverse imaging in the majority of patients.

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Disclosure of conflict of interest

None.

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