Utility of the Vidian Canal in Endoscopic Skull Base Surgery: Detailed Anatomy and Relationship to the Internal Carotid Artery

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■ OBJECTIVE: **To investigate key anatomic features of the vidian canal that have a critical role in planning and performing endoscopic skull base surgeries.**

■ METHODS: **We reviewed skull base computed tomographic images of 640 consecutive subjects. Studies were analyzed in axial, coronal and sagittal planes.**

■ RESULTS: **The mean (±SD) length of the vidian canal was 15.4 ± 2.0 mm in female subjects and 16.6 ± 1.7 mm in male subjects, and the difference between genders was statistically significant ($P < 0.001$). The most common rostral-caudal course of the vidian canal was medial to lateral and was followed by the straight course, tortuous course, and lateral-to-medial course. The frequency of pneumatization pattern from most common to least common was types 0, III, II and I. Of 342 evaluated sides, the vidian canal was located below the level of the anterior genu of petrous ICA in 303 (89%) sides, at same level with the anterior genu of petrous ICA in twenty-five(7%) sides, and above the level of the anterior genu of petrous ICA in fourteen(4.1%) sides.**

■ CONCLUSIONS: **A variety of previously undefined features of the vidian canal that can alter the course of surgical procedure were defined. The position of the vidian canal with respect to the petrous internal carotid artery (ICA) was extensively described. From a surgical standpoint, a working room inferior and medial to the vidian canal might not always be a safe approach, because the vidian canal could be located superior to the level of the anterior genu of petrous ICA according to our findings in the present study.**

INTRODUCTION

The skull base, where a large number of small anatomic structures and major pathways intertwined in a narrow space, is one of the most complex anatomic regions of the human body. It has inherent diagnostic and therapeutic challenges for radiologists and surgeons. A thorough understanding of detailed anatomy and the structural relationships in this region is a prerequisite for accurate diagnosis and preoperative planning. Moreover, with entry of guided stereotactic surgery into everyday practice, imaging has become an integral part of the treatment for excision of skull base pathologies.[1-3]

The vidian canal harbors the vidian artery, vein, and nerve; it lies along the base of medial pterygoid plateau, and it is almost always identifiable on CT.[4] Anteriorly it opens into the posterior medial wall of the pterygopalatine (sphenopalatine) fossa (PPF) and posteriorly continues to the upper part of the anterolateral edge of the foramen lacerum with close proximity to the anterior genu of the petrous internal carotid artery (ICA).[4,5] The vidian canal is a crucial anatomic landmark in planning and performing transpterygoid endoscopic endonasal surgery.[5,6] For example, with the medial pterygoid approach, the vidian artery is traced along its course to reach the second genu of the ICA, after which safe lateralization of the artery is done to expose the lesions

Key words
- Anatomic variation
- Endoscopic surgery
- Multidetector computed tomography
- Skull-base
- Sphenoid sinus
- Vidian canal

Abbreviations and Acronyms
CT: Computed tomography
ICA: Internal carotid artery
MDCT: Multidetector computed tomography
pICA: Petrous horizontal segment of the ICA
PPF: Pterygopalatine (sphenopalatine) fossa

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of the petrous apex directly with greater surgical space.[7] The same rule applies to transpterygoid infrapetrous approach, in which the vidian artery is again traced back to the second genu of the ICA, where the paraclival vertical segment joins the petrous horizontal segment.[7] As a result, at the preprocedural stage, an appreciation of the relationship between vidian canal and ICA on computed tomography (CT) is critical to avoid catastrophic bleeding during surgery. Few studies are available in the English-language literature regarding detailed anatomy of the vidian canal, mainly because of the recent recognition of its importance for endoscopic skull base surgery.[8-11] Despite rapid technical improvements in minimally invasive skull base procedures, injury to the ICA has been reported to be as high as 9%, particularly in extended endonasal approaches.[12] One can assume unusual anatomic variation of pertinent structures as a potential hazard with significant procedural ramifications.

In the present retrospective observational anatomic study, we aimed to investigate detailed anatomy of the vidian canal and its relationship with adjacent anatomic structures, particularly the anterior genu of the petrous segment of the ICA, to contribute to the planning and performing endoscopic skull base procedures.

MATERIALS AND METHODS

Six hundred forty consecutive patients who underwent high-resolution multislice skull base CT (Philips Brilliance V2.6.1, Cleveland, Ohio, USA) were reviewed retrospectively. Those with significant pathology in the skull base and paranasal sinuses (e.g., lesions causing sinus opacification or space occupying mass lesions) were excluded from this study (except for patients with minimal mucosal thickening or insignificant maxillofacial pathologies). Studies with poor image quality in the region of interest resulting from patient-related factors, foreign bodies, or technical issues were excluded. Because the sphenoid sinus pneumatization has been shown to continue until the age of 16, subjects younger than 18 years were also excluded.[13] Remaining normal or near-normal MDCT skull base studies were included. The study protocol was approved by the local ethics committee with the exemption of an informed consent requirement, because no patient data was involved in this retrospective study. Subjects were scanned from the inferior border of the mastoid bone through the superior edge of the frontal sinus. All studies were examined at workstations in the department of radiology in axial, sagittal, coronal, and oblique reformats with 0.6-mm thickness. A radiologist (M.E.A.) with 8 years of experience in radiology and neuroradiology training analyzed all the images. Blinded to the first reviewer's findings, an attending neuroradiologist (N.A.) with more than 20 years of experience and expertise in head and neck imaging re-evaluated the initial findings in a subset of subjects. Multiple anatomic features of the vidian canal were analyzed in all 3 planes along with oblique reconstructions when needed. The rostral-caudal course of the vidian canal was noted in 3 different fashions as medial-to-lateral oblique course, straight anterior posterior course, and lateral-to-medial oblique course. The length of the vidian canal was defined as the distance from posterior wall of PPF to the opening point at the front border of the carotid canal, and it was measured on axial images. The location of the vidian canal with respect to the anterior genu of the petrous horizontal segment of the ICA (pICA) was examined on sagittal and axial images and was noted as below, coaligned, or above the level of the pICA. Also recorded was whether the vidian canal and its posterior aperture were visible on the same axial section with the pICA. Classification of the amount of pneumatization around the vidian canal was devised from the study by Vescan et al.[8] as the following degrees: 0, no air around vidian canal on coronal images; I, 1%–33% of the vidian canal's circumference surrounded with air; II, 33%–66% of the vidian canal's circumference surrounded with air; and III, 67%–100% of the vidian canal's circumference surrounded with air. Dehiscence of the vidian canal was defined as partial or complete absence of bony covering of the canal; it was also investigated on coronal images.

Statistical analyses were done after subjects were grouped according to their demographics. Radiologic variables were also evaluated accordingly. Statistical significance level was set at 5% for all analyses ($P < 0.05$). Continuous and categorical variables were divided into groups and presented graphically. Student *t* test was used to test the statistical difference between the groups of continuous variables. The relationship between categorical variables and genders were evaluated with a chi-squared test. Fisher exact test was used when the number of subgroup variables within the groups was less than 10. Findings in all cases included in this study were evaluated bilaterally. Pearson correlation test was used for evaluation of the statistical relationship between age and continuous variables. R statistical environment (R Studio for Mac OS version 0.9.501) or Microsoft Excel 2011 for Mac OS (Microsoft, Redmond, Washington, USA) was used for all statistical analyses and graphics. GIMP (GIMP for mac OS, version 2.8.16) was used for drawing colored illustrations.

RESULTS

Skull base MDCT studies of 640 consecutive patients were evaluated. Those with improper scanning technique for multiplanar evaluation of small anatomic structures ($n = 114$), artifactual degradation ($n = 96$), and age younger than 18 years ($n = 76$) were excluded. Patients with significant inflammatory or tumor pathologies of the paranasal sinuses were also excluded ($n = 183$). Remaining normal or near-normal MDCT skull base studies of nonconsecutive 171 (342 sides) cases were included in this study; 55% of patients included in the study ($n = 94$) were female, 45% of patients ($n = 77$) were male, and age range was 18–72 years (mean $\pm$ SD 34.6 $\pm$ 13.2 years). Of 342 evaluated vidian canals, 315 canals (92.1%) showed a medial-to-lateral rostrocaudal course, 20 canals (5.8%) showed a straight rostral-caudal course, 5 canals (1.5%) showed tortuous-kinked course, and 2 canals (0.6%) showed a lateral-to-medial rostrocaudal course in the axial plan. Straight and tortuous courses were more common in male patients, whereas a medial-to-lateral course was more common in female patients ($P < 0.001$). The mean ($\pm$SD) length of the vidian canal was 15.4 $\pm$ 2.0 mm in female patients and 16.6 $\pm$ 1.7 mm in male patients, and the difference between both sexes was statistically significant ($P < 0.001$). However, there was no statistically significant difference between the mean length of the right and left sides within the groups (male right side, 16.5 $\pm$ 1.8 mm; male left side, 16.49 $\pm$ 1.7 mm; female right side: 15.44 $\pm$ 2.0 mm; female left side, 15.47 ± 2.1 mm. Relationship between age of the subjects and length of the canal was assessed with Pearson correlation analysis (P and r values for right and left, respectively: 0.52, 0.83, −0.31, and −0.10). No significant correlation was detected between the length of the canal and age of the subjects. Of 342 evaluated instances, the vidian canal was located below the level of the pICA in 303 sides (89%), at the same level with the pICA in 25 sides (7%), and above the level of the pICA in 14 sides (4.1%). To test the reproducibility of this finding reliably, a second radiologist (N.A.) also evaluated the position of the vidian canal with respect to the pICA in 20 randomly selected subjects (40 sides). Both readers agreed in all cases. There was no statistically significant difference between female and male subjects in case of inferior location and the same level location of the vidian canal with respect to the pICA. However, Frequency of the superiorly located vidian canal was significantly higher in male subjects ($P < 0.001$; Figure 1) than that of females. While the vidian canal and its caudal aperture were visible in the same axial plane with the pICA in 259 sides (76%), the canal and the pICA were not visible in the same axial plane in 83 instances (24%). The amount of vidian canal pneumatization was best evaluated in the coronal plane (Figure 2). The degree of pneumatization was 0 in 164 sides (48%), I in 29 (8%) sides, II in 60 (18%) sides, and III in 89 (26%) sides. The most common type of vidian canal pneumatization degree was 0 in male and female subjects (incidence was 46% in female subjects and 50% in male subjects). The frequency of other types varied according to gender. In female subjects, the frequencies of pneumatization patterns were 22.8% for type II, 23.4% for type III, and 7.4% for type I. In male subjects, the frequencies of pneumatization patterns were, 29.8% for type III, 10.3% for type II, and 9.7% for type I (9.7%). Dehiscence of the bony covering of the vidian canal was evident in 151 sides (44%) on coronal images. Dehiscence was right sided in 12 subjects, left sided in 31 subjects, and bilateral in 54 subjects.

DISCUSSION

In this study, we demonstrated the detailed anatomic features of the vidian canal and related structures, which are critical in planning and performing endoscopic skull base surgery. The length, rostrocaudal course, pneumatization pattern, and position of the vidian canal with respect to the posteriorly positioned petrous ICA were investigated. The most common course was medial-to-lateral followed by straight course, tortuous course, and lateral-to-medial course in descending frequency. The third most common course, defined in the present study as tortuous course, has not been previously reported according to our literature review. The most commonly observed pneumatization pattern was type 0, which was defined as total absence of air around the vidian canal. We also report the position of the vidian canal with respect to posteriorly lying pICA, a structure of paramount importance during anterior endoscopic surgical approach. The vidian canal was located below the level of the pICA in the vast majority of subject. In the majority of cases, the vidian canal and the pICA were intersected with a virtual horizontal line drawn from the vidian canal in sagittal plane (Figure 3). However, either located below or above the level of pICA, the posterior aperture of the vidian canal was not coexisting with the pICA in the same axial plane in a quarter of instances, meaning a clearance of at least 0.6 mm or more.

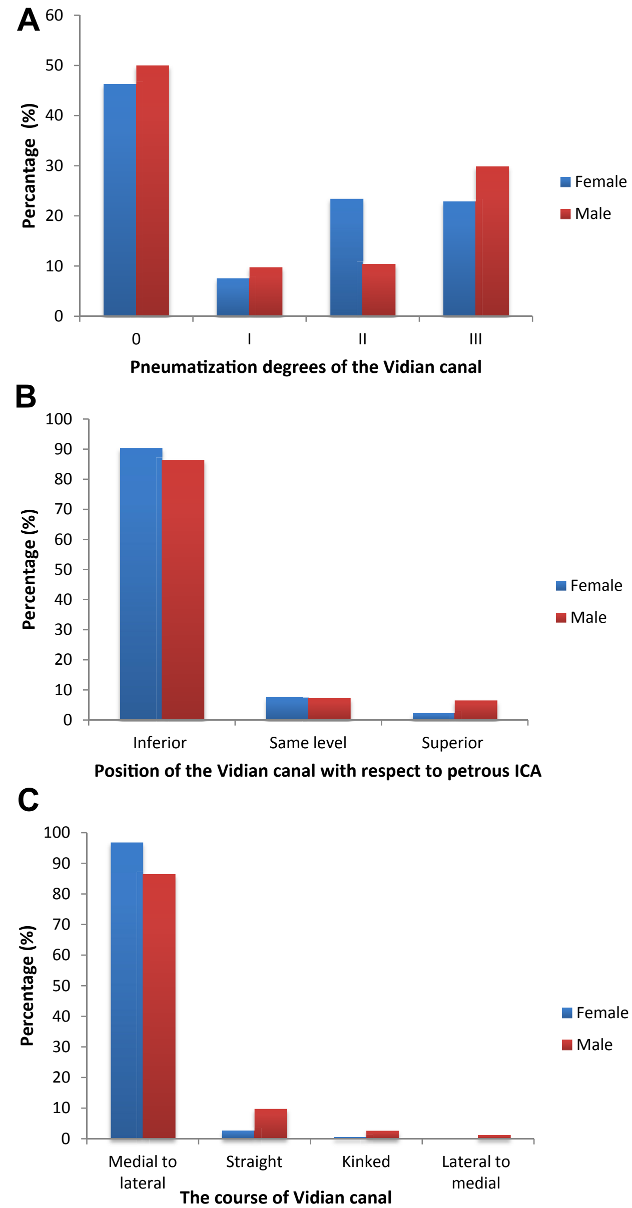

Figure 1. Bar charts demonstrate dispersion of radiologic variables of the vidian canal according to subjects' sex. (**A**) Note that all but type II pneumatization were observed more commonly in males than in females. (**B**) Dispersion of the position of the vidian canal with respect to the internal carotid artery (ICA). Note that the superior location of the vidian canal is more common in males, and that difference was statistically significant. (**C**) Dispersion of rostrocaudal course of the vidian canal according subjects' sex. Note that less frequent forms of the canal's course are more commonly observed in males.

In the last few decades, endoscopic skull base surgery applications have gained popularity over conventional surgical procedures,

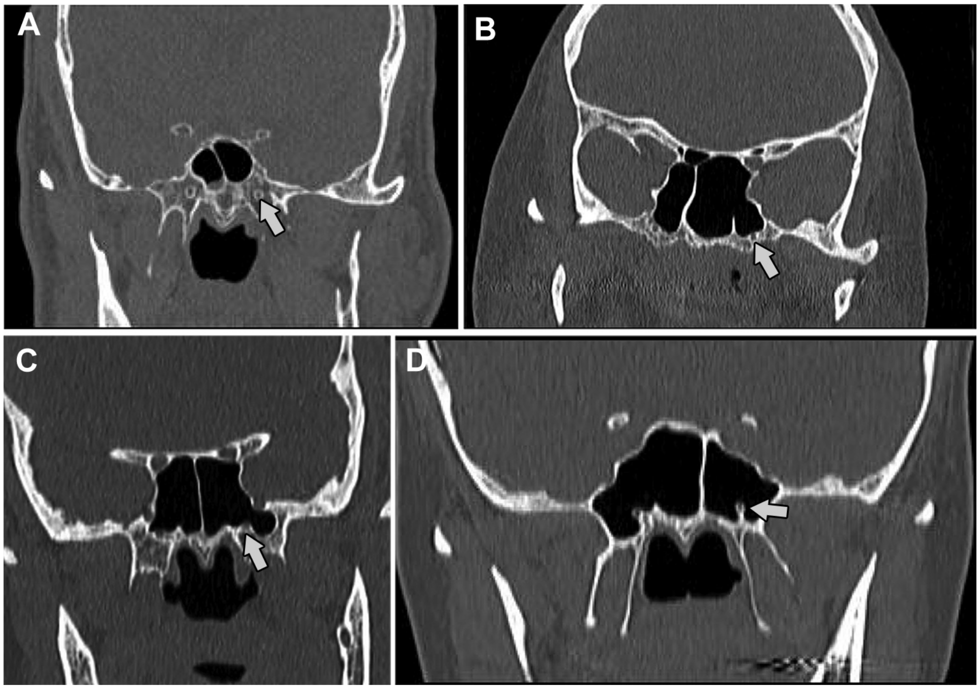

Figure 2. Anatomic variations of the vidian canal depicted on coronal reformatted CT images as degrees 0, I, II, and III in **A**, **B**, **C**, and **D**, respectively. Arrows indicate the vidian canals on CT scans obtained from four individuals. The spectrum of vidian canal pneumatization ranges from completely embedded within sphenoid bone (**A**) to completely embedded within sphenoid sinus air (**D**).

and imaging has a key role in planning and performing these sophisticated multidisciplinary procedures. The vidian canal is a recently described anatomic landmark, which facilitates accurate intraoperative localization of the pICA (Figure 4). In addition, identification of the vidian canal is also important to protect the vidian nerve itself from damage, which can cause decreased tear secretion leading to corneal ulcers and blindness.[14] When the bony surrounding of the canal is being drilled during an anterior surgical approach, the anatomic structure at the posterior aperture of the vidian canal has a vital importance, because, as we also demonstrated in the present study, most of the times this structure is a pICA.[8,15,16] In contrary to our findings, Vescan et al.[8] reported that the vidian canal was always (100% of their subjects) located below the level of the pICA in their retrospective study conducted on 44 subjects, and their findings correlate well with other studies in the literature.[5,11] As a result, they proposed a safe drilling of the vidian canal from inferior 180 degrees during anterior endoscopic approaches. A recent study conducted on CT scans of 50 subjects by Mason et al.[17] has described the position of the vidian canal either at (34%) or below (66%) the level of the pICA on sagittal reformatted CT scans. A superiorly located vidian canal had not been reported in previous studies until the recent study by Gao et al.[10] In their prospective study conducted on CT studies of 28 subjects, they reported a significant incidence (6.9%) of superiorly located vidian canal with respect to posteriorly lying petrous ICA for the first time.[10] Although their study population is significantly smaller than ours, their findings correlate well with our study (4.1% in our present study). Unlike what was previously reported, together our studies demonstrate that inferior circumferential drilling of the vidian canal might not be granted safe, and it might potentially jeopardize a posteriorly neighboring pICA. Despite its low incidence, superiorly located vidian canal was significantly more commonly observed in male subjects in our study. No significant sex differences were previously reported in this regard. We found no significant sex preference in the groups of inferiorly located or coaligned vidian canals with respect to pICAs.[5,8,11] Apart from the findings on the position of the vidian canal on sagittal and coronal reformatted images, another compelling finding in terms of the location of the vidian canal with respect to a pICA in the present study was coexistence of the vidian canal, its posterior aperture, and carotid canal on the same axial view. We found that, located either above or below the level of the ICA, those structures were not visualized in the same axial image in approximately one quarter of instances, meaning at least 0.6 mm of clearance between the vidian canal and ICA given the slice thickness of our CT scans.

The pneumatization pattern of the vidian canal has a number of implications during an anterior endoscopic approach. Being surrounded by air or bone alters the amount of drilling and available surgical room, thus the visualization of adjacent structures and the lesions that are aimed to be reached. The amount of pneumatization and outcomes of the degree of pneumatization on the relationship of anatomic structures have been previously studied using variable classification approaches to better the anatomic knowledge of this complex region, to facilitate surgical procedures, and to increase success rates of endoscopic approaches.[8,10,11,18-22] The reported

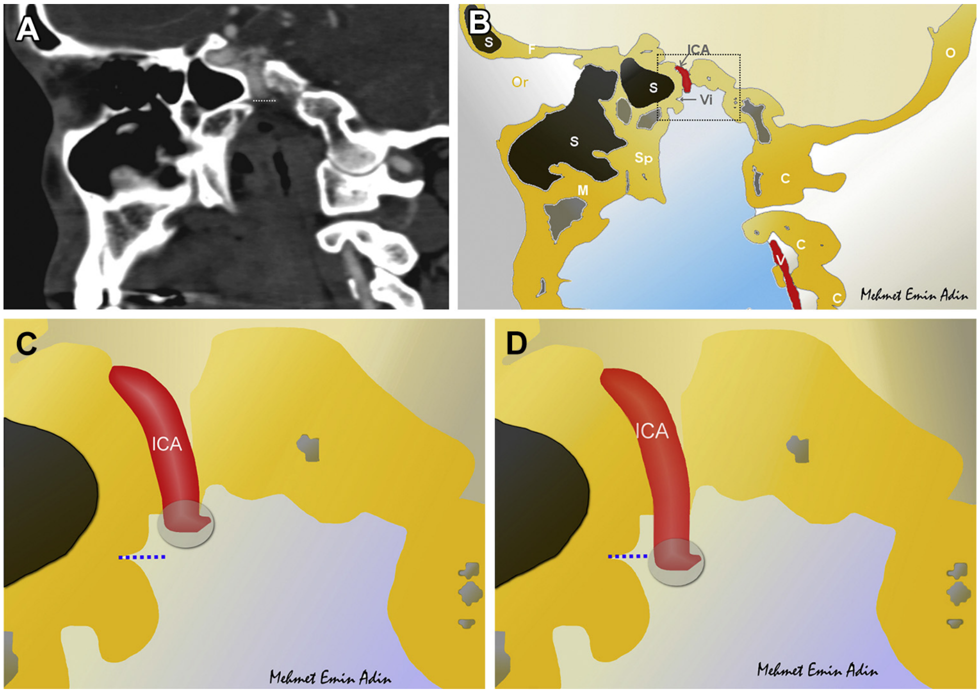

Figure 3. (**A**) Sagittal reformatted computed tomography angiography (CTA) image demonstrates the position of the vidian canal with respect to the petrous horizontal segment of the internal carotid artery (pICA). A virtual line drawn from the posterior aperture of the vidian canal runs below the level of the ipsilateral pICA, which was the most common case in our present study. (**B**) Schematic illustration of the lateral view of a sagittal CTA section. (**C**, **D**) Close-up views of the dashed box area within **B** demonstrate the position of the vidian canal with respect to the pICA. Horizontal segment of the pICA forms the anterior genu, from where it turns vertically to form the paraclival segment (the horizontal segment is not shown in here, as it lies posteriorly in this projection). The pICA is above the level of posterior aperture of the vidian canal in **C** and at the same level in **D**. Note the lowest point of the paraclival segment of the ICA is the anterior genu of the horizontal petrous segment of the ICA (*shaded elliptical area*). The *dashed blue line* designates the virtual horizontal projection of posterior aperture of the vidian canal. Vi, vidian canal; ICA, internal carotid artery; S, Sinus air; F, Frontal bone; O, occipital bone; Sp, sphenoid bone; M, maxillary bone; V, vertebral artery; Or, orbit; C, cervical spine.

frequencies of the degree of pneumatization about the vidian canal vary among authors, with a higher incidence of pneumatized vidian canals (i.e., type I, II, and III according to our classification) compared with those completely embedded in sphenoid bone. Although the overall frequency of pneumatized vidian canal was also marginally higher in our study, when compared with the studies in the literature, our present study shows the highest proportion of vidian canals that are totally embedded within bone (48% of our patients had no air surrounding the vidian canal). The next highest rates of poorly pneumatized vidian canal were reported by Yeğin et al.[23] and Yazar et al.,[22] with 39% and 36% of vidian canals being totally embedded in the bone, respectively.[23] Interestingly, these studies were also conducted in Turkey, which might implicate an ethnical anatomic alteration. A study from Japan also reported high rates of poorly pneumatized vidian canal rates when compared with studies conducted on white populations.[8,11] Among other previously reported findings showing variability based on ethnic and demographic factors, this situation might also highlight the importance of surgical planning with consideration of the population on which it is being performed. Moreover, although type 0 was the most common finding in both sexes, the frequency of other types varied according to subject's sex. Types II, III, I, were found in female patients and types III, II, I were found in male patients, in respective descending order. Except for the recent study by Yeğin et. al.,[23] which also demonstrated slight gender preferences, there was no significant sex preference in previous studies.[5,8,11] This finding might be related to differences in subject sizes between study cohorts, as Yeğin et al.,[23] like our present study, also conducted their study on a large cohort. Individual study protocols and measurement techniques adopted by researchers might also have affected the findings. More studies with reproducible study protocols could help to verifying these findings.

As the vidian nerve lies immediately underneath the sphenoid sinus mucosa, the bony dehiscence of vidian canal could have implications regarding potential injury to the vidian nerve. Conversely, the dehiscence of the canal can sometimes help surgeons in determining the best approach. For example, in vidian neurectomy, which is performed in cases of intractable vasomotor rhinitis, a transsphenoidal approach might be preferred over other available endoscopic techniques.[24] Bony dehiscence of the vidian

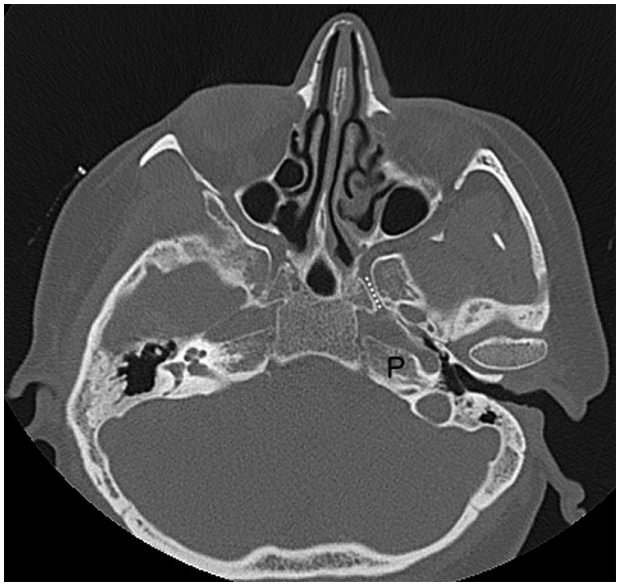

Figure 4. Axial reformatted CT image demonstrates the course of the vidian canal (*dashed line*), which immediately opens at the level of the pICA. In extended transpterygoid endoscopic procedures, the pICA could be safely lateralized to provide a surgical room to reach lesions of the petrous apex (P).

canal was found in 44% of instances in our study, with a notably higher frequency on the left side. The reported incidence of vidian canal dehiscence, like in dehiscence of other anatomic structures, differs among authors, with a wide range of frequency from 6% to 37%.[16-19] Our results show a higher frequency of bony dehiscence of vidian canal when compared with the existing literature.

Preoperative mapping of the vidian canal course using high resolution CT has been shown to improve the surgical planning with favorable clinical outcomes.[24] The course of the vidian canal in the axial plane has also recently been described by a few authors. A medial-to-lateral rostrocaudal course followed by a straight course were the most common anatomic types in all reported series, with the former being significantly more frequent than the latter.[8,10,11] Although some authors reported a lateral to medial course, others did not report such a course.[8,10,11,25] However, similar to the findings in our present study, the frequency of lateral to medial course was less than 1% when reported, with the exception of the study by Kim et al.[25] that reported 19% lateral to medial course in the Korean population. The frequency of lateral-to-medial course reported by Kim et. al. is remarkably higher than the rest of the studies in the English-language literature, and it has not been verified by following studies. All 3 patterns of vidian canal course were evident in our study. To our knowledge, we report for the first time a "tortuous" or "kinked" course of the vidian canal. This pattern was the third most common vidian canal course after medial-to-lateral and straight courses and was followed by lateral to medial course (92.1%, 5.8% 1.5%, and 0.6%, respectively). Kinked course of the vidian canal can hinder the surgical maneuvers when used as a guide in an anterior endoscopic approach. The rostrocaudal length of the vidian canal is also critical in the anterior approach in endoscopic skull base procedures, because, along with the amount of pneumatization, it alters the amount of bone that needs to be drilled to reach the posterior end of the canal. The length of the vidian canal has been studied by few authors using different measurement techniques, and it was reported to range from 7 to 20 mm.[5,8,11,26] In our present study, the mean length of the vidian canal was similar; however, unlike the previous studies, we found a statistically significant difference between sexes ($P < 0.001$). The length of the vidian canal was slightly higher in male subjects compared to that of female participants. The difference between right and left sides of the same-sex subjects was statistically insignificant in our study, in accordance with previous reports.[5,8,11,26] The main limitation of our study is the lack of assessment of the effects of the anatomic features investigated on clinical outcomes. Although we showed utmost attention to reviewing anatomic variables in all 3 planes and oblique reconstructions when needed, the prevalence of findings like bony dehiscence might have been affected by inherent limitations of CT imaging. This might also explain the wide range of reported prevalence in the literature.

CONCLUSION

In this study, we reported the detailed anatomic features of the vidian canal, which is an important landmark in planning and performing endoscopic skull base surgery. Unlike what was reported in previous studies, we showed that inferior-medial drilling of the vidian canal might not always be safe, as it might be located superior to the level of the pICA in a small percentage of patients.

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