Relation between volume of sphenoid sinuses and protrusion of Vidian nerve: possible applications to Vidian neurectomy

Daniele Gibelli[1], MD, PhD (0000-0002-9591-1047), Michaela Cellina[2], MD (0000-0002-7401-1971), MD, Stefano Gibelli, MD[3], Annalisa Cappella[1], BSc, PhD, MA (0000-0002-4527-4203), Antonio Giancarlo Oliva[2], MD, Giovanni Termine[3], MD, Claudia Dolci[1], MD (0000-0002-3060-4097), Chiarella Sforza[1], MD (0000-0001-6532-6464)

1) Dipartimento di Scienze Biomediche per la Salute
   Università degli Studi di Milano
2) Reparto di Radiologia
   Ospedale Fatebenefratelli
   ASST Fatebenefratelli Sacco, Milano
3) Reparto di Otorinolaringoiatria
   Ospedale Fatebenefratelli
   ASST Fatebenefratelli Sacco, Milano

Running head: influence of sphenoid sinus volume on protrusion of Vidian nerve

MS accepted for publication in Surgical and Radiologic Anatomy, dec 2019

Corresponding author: Dr Daniele Gibelli, MD, PhD
Dipartimento di Scienze Biomediche per la Salute
Università degli Studi di Milano
Via Mangiagalli 31, 20133, Milano, Italy
tel. +39-02-50315399
daniele.gibelli@unimi.it
ORCID ID: 0000-0002-9591-1047

Conflict of interest

None.

Abstract

Purpose: Vidian neurectomy is a surgical procedure applied to different pathological conditions, including chronic rhinitis and sphenopalatine neuralgia. The choice of the correct surgical approach depends upon the possible protrusion of Vidian nerve into the sphenoid sinuses.

The present study analyses the possible relationship between protrusion of Vidian nerve and volume of sphenoid sinuses.

Methods: In total, 320 maxillofacial CT-scans were retrospectively assessed. Subjects equally divided among males and females (age range 18-94 years) were divided into three groups according to the profile of Vidian nerve protrusion; type 1: Vidian nerve inside the sphenoid corpus; type 2: partially protruding into the sphenoid sinus; type 3: entirely protruding into the sphenoid sinus through a stalk. Volume of sphenoid sinuses was extracted through ITK-SNAP free software and automatically calculated.

Possible statistically significant differences in prevalence of the three types between males and females were assessed through Chi-squared test ($p<0.05$). Differences in volume of sphenoid sinuses in subjects included within the three types were assessed through one-way ANOVA test ($p<0.05$), separately for males and females.

Results: Type 2 was the most prevalent (46.6%), followed by type 1 (38.8%) and type 3 (14.7%), without significant differences according to sex ($p>0.05$). Volume significantly increased passing from type 1 to type 3 both in males ($p<0.01$) and in females ($p<0.01$).

Conclusions: The results prove the existence of a strict relationship between sphenoid sinuses pneumatization and protrusion of the Vidian canal and give a contribution to the knowledge of this important anatomical variant in endoscopic surgery.

Keywords: sphenoid sinus, Vidian nerve, pterygoid canal, CT-scan, 3D segmentation

Introduction

The Vidian nerve is formed by the confluence of the deep petrosal nerve, originating from the sympathetic carotid plexus, and the greater petrosal nerve, a parasympathetic branch of the facial nerve [15]. It runs through the pterygoid canal up to the pterygopalatine fossa where its parasympathetic part synapses in the pterygopalatine ganglion. Postganglionic branches provide innervation to the lacrimal gland and to nasal and palatal mucosa [15]. In consideration of its functions, the Vidian nerve is the target of several surgical procedures of neurectomy, usually applied to chronic rhinitis, sphenopalatine neuralgia and "crocodile tears" syndrome [6,12,16,22].

Chronic rhinitis is usually characterized by clear rhinorrhea, nasal obstruction, postnasal drip and sneezing; patients who do not see improvements through pharmacological therapy are usually treated through Vidian neurectomy [12,22]. Sphenopalatine neuralgia involves sphenopalatine ganglion and leads to unilateral headache, usually localized in the retroorbital region and eye [6]. "Crocodile tears" syndrome occurs in rare cases of facial nerve lesions followed by misdirected regeneration between salivatory axons directed to chorda tympani and preganglionic fibres to sphenopalatine ganglion [16].

In all the previously mentioned cases, Vidian neurectomy represents a valid treatment: various approaches have been suggested, being the transnasal one the most frequent [27]. In this way, the Vidian canal can be reached through two different routes: the sphenoid sinuses [10] or the pterygopalatine fossa through a transmaxillary approach [7,8]. The two routes provide different advantages and disadvantages, but their choice is strictly linked to anatomical characteristics of the Vidian canal.

The Vidian canal runs from the anterior edge of the foramen lacerum anteriorly through the sphenoid corpus and the medial pterygoid plate to the posterior wall of the pterygopalatine fossa [3]. However, the position of the Vidian canal depends upon the pneumatization of sphenoid sinuses: when they are wide, the Vidian nerve may protrude into the sphenoid sinuses, partially (on the floor of the sphenoid sinuses, separated by a thin bone layer) or completely [22]. In these cases, transsphenoidal approach represents the most adequate one, as it allows surgeons to reach the Vidian nerve directly or to easily identify its position. In case where the Vidian nerve does not protrude into the sphenoid sinuses, an anterograde transmaxillary approach through the pterygopalatine fossa at the exit of the Vidian canal is suggested; however, this type of intervention is more difficult to perform and brings about a higher risk of damaging the sphenopalatine artery with consequent bleeding [7,8]. Therefore, the

prevalence and characteristics of Vidian canal protrusion into the sphenoid sinuses are of special interest in these surgical practices.

With time, several articles have analysed the prevalence of this anatomical variant in their respective populations [1,3,9,10,13-15,20,21,24,25]. However, no study has focused on the possible relationship between Vidian nerve protrusion and volume of sphenoid sinuses so far.

This study aims at filling this gap, analysing the volume of sphenoid sinuses in different profiles of Vidian canal protrusion. The results will improve the knowledge of this anatomical variant.

Materials and methods

From a hospital CT-scan database 320 patients (equally divided among males and females) were retrospectively assessed. Age of males and females was 50.2±19.3 years and 52.5±20.8 years, respectively (age range: 18-94 years. The study used maxillofacial CT-scans performed through a second generation dual-source scanner, Somatom Definition Flash (Siemens, Forchheim, Germany), with the following parameters of acquisition: kV: 120, mAs: 320, collimation: 40 x 0.6 mm, tube rotation: 1 sec; reconstruction thickness: 3 mm; reconstruction filters: H21s smooth for soft tissues and H60 sharp for bone. CT-scans were requested for screening of cranial fractures in trauma (57.3%), sinusitis (20.0%), neurological symptoms (12.7%) and nasal polyps (10.0%). Patients affected by traumatic injuries and pathologies involving the sphenoid sinuses, and congenital or acquired cranial deformation were excluded from the study.

All the images were anonymized: the study follows local and international laws and guidelines (Helsinki Declaration). The study was approved by the local ethical committee (7331/2019).

CT-scans were then analysed to verify the possible protrusion of Vidian nerve into the sphenoid sinuses: in detail, each subject was classified according to Yeh and Wu [25] as follows: type 1, Vidian nerve inside the sphenoid corpus; type 2, Vidian nerve partially protruding into the sphenoid sinus (Vidian nerve beneath the floor of the sphenoid sinus and protruding into the sphenoid sinuses); type 3, Vidian nerve entirely protruding into the sphenoid sinus through a stalk (Fig. 1).

The 3D model of sphenoid sinuses was obtained from each CT-scan through ITK-SNAP free software (Fig. 2) according to a semi-automatic approach already described and validated in previous publications [5,26]. Volume of both sphenoid sinuses in cm^3 was automatically extracted through VAM® software (Vectra Analysis Module,

version 2.8.3, Canfield Scientific®, Inc.). Prevalence of different types, and average volume of sphenoid sinuses of subjects included in each type, were calculated, both in males and females.

Possible statistically significant sex differences in age and prevalence of the three types were respectively assessed through Student's t and Chi-squared tests ($p<0.05$). Differences in volume of sphenoid sinuses in subjects included within the three types were assessed through one-way ANOVA test ($p<0.05$), separately for males and females. Post-hoc test was performed through Tukey HSD test ($p<0.05$). All the statistical analyses were performed through SPSS® software.

Results

No statistically significant age difference was observed according to sex (Student's t-test, $p>0.05$).

Overall results are exposed in Table 1. Distribution of different variants of Vidian nerve protrusion was similar in both sexes: type 2 was the most prevalent (46.6%), followed by type 1 (38.8%). Type 3 was the rarest (14.7%). No statistically significant differences in prevalence of each protrusion type were found according to sex (Chi-square: 3.71; $p=0.156$). The pattern of protrusion of Vidian canal was always the same on both the sides.

Volume of sphenoid sinuses was significantly different among the three types both in males (F: 36.04; $p<0.0001$) and in females (F: 50.48; $p<0.0001$). In detail it significantly increased passing from type 1 to type 3 both in males ($p<0.01$) and in females ($p<0.01$).

Discussion

Morphology and size of sphenoid sinuses represent crucial information in endoscopic surgery when a transsphenoidal route is considered [2]. Sphenoid sinuses develop as an invagination of nasal mucosa within the bone between the third and fourth fetal month, and progressively increase their size up to adolescence, when they reach the final morphology [2]. The possible widening of air spaces may lead to a close relationship with several sensitive structures, including the internal carotid artery, the optic nerve and the Vidian nerve [2]. Therefore,

anatomical studies focusing on sphenoid sinuses are becoming more and more important for a correct surgical planning [18].

Vidian neurectomy represents a surgical procedure applied with success to different pathological conditions, thanks to the improvement of endoscopic procedures [6,12,16]: two different approaches are available for Vidian neurectomy, the transmaxillary and the transsphenoidal one. The former one usually passes through the lateral wall of the nasal cavity omolaterally by removing the middle turbinate, and reaches the pterygopalatine fossa through the posterior wall of the maxillary sinus; it provides the shortest path to reach the Vidian nerve, but is affected by possible impairments of nasal cavity heating and humidification for the excision of the middle turbinate [17,18,19,23,26]. The transsphenoidal approach does not request the ligation of the sphenopalatine artery and is affected by a lower risk of damaging the pterygopalatine ganglion, as it usually does not reach the pterygopalatine fossa; however, the choice of the transsphenoidal approach is dependent upon the type of Vidian nerve exposure into the sphenoid sinuses [21] (Table 2). In detail, the presence of a Vidian canal embedded within the sphenoid floor leads to the choice of a transmaxillary approach through the pterygopalatine fossa, more difficult and affected by a higher risk of bleeding [7,8].

Literature justified the intimate relationships of vascular and neurological structures with sphenoid sinuses as caused by the expansion of air cavities around them during the development [4,11]. However, at our knowledge, no study has analysed the relationship between Vidian nerve protrusion and volume of sphenoid sinuses. Only Kazkayasi et al. verified that frequency of Vidian nerve protrusion increases with size of pterygoid pneumatisation [9]. However, the correlation between the sphenoid total volume and prevalence of each type of Vidian nerve protrusion remains to be ascertained.

The present study aimed at filling this gap, comparing the volume of CT reconstructed sphenoid sinuses in different types of Vidian nerve protrusion. Results show that Vidian nerve protrusion is strictly dependent upon the pneumatisation of sphenoid sinuses, and that volume in each type is significantly different from that found in the other groups. Therefore, we can conclude that different degrees of Vidian nerve exposition inside the sphenoid sinuses may be caused by the progressive increase in volume of air cavities, as also hypothesized by literature [4]. The present results may also be useful for the planning of endoscopic procedures, as they provide the volume standards for each type of protrusion: accordingly, the sphenoid sinus volume represents an important variable for the choice of the type of surgical procedure to apply, with the prediction of possible risks which may be encountered.

The prevalence of each type of protrusion in the Italian population was given, as well. Surprisingly, in literature several studies give the prevalence of Vidian canal protrusion on CT-scans [1,3,9,10,13-15,20,21,24,25], but none of them explores its possible relationship with sphenoid sinus volume. The comparison of the present data with existing literature shows that type 3 (complete protrusion of Vidian nerve through a stalk) is always reported as the rarest one, although with different percentages (Table 3). On the other side, prevalence of type 1 or type 2 varies among different populations, sometimes within the same country [1,24]. This limited comparison shows that ethnic variability is a key factor in influencing this anatomical variant.

This study is affected by the limits that it focuses only on the relation between protrusion of Vidian nerve and volume of sphenoid sinuses: however, protrusion of Vidian nerve is not sufficient for the choice of a transsphenoidal approach. For example, a lateral position of the Vidian nerve in relation with the posterior end of the middle turbinate represents another factor to consider in the choice of the surgical approach [21].

Conclusion

In conclusion, this article provides novel data concerning the anatomical variants of Vidian canal: results may be useful in endoscopic surgery and for a correct choice and planning of surgical approach.

Conflict of interest

None.

Authors contribution

D Gibelli: protocol development, data collection and management, data analysis, manuscript writing and editing

M Cellina: protocol development, data collection, manuscript writing and editing

S Gibelli: data collection and management, data analysis, manuscript editing

A Cappella: data analysis, manuscript editing

AG Oliva: data collection and management, manuscript editing

G Termine: data collection and management, manuscript editing

C Dolci: data management, data analysis, manuscript editing

C Sforza: data management, data analysis, manuscript editing

References

1) Acar G, Cicekcibasi AE, Cukurova I, Ozen KE, Seker M, Guler I (2017) The anatomic analysis of the Vidian canal and the surrounding structures concerning Vidian neurectomy using computed tomography scans. Braz J Otorhinolaryngol 85(2):136-143
2) Anusha B, Baharudin A, Philip R, Harvinder S, Mohd Shaffie B (2014) Anatomical variations of the sphenoid sinus and its adjacent structures: a review of existing literature. Surg Radiol Anat 36:419-427
3) Bahsi I, Orhan M, Kervancioglu P, Yalcin ED (2019) The anatomical and radiological evaluation of the Vidian canal on cone-beam computed tomography images. Eur Arch Otorhinolaryngol 276(5):1373-1383
4) Catala M (2003) Embryology of the sphenoid bone. J Neuroradiol 30:196-200
5) Gibelli D, Cellina M, Gibelli S, Oliva AG, Codari M, Termine G, Sforza C (2018) Volumetric assessment of sphenoid sinuses through segmentation on CT-scan. Surg Radiol Anat 40(2):193-198
6) He W, Zhang Y, Long T, Pan Q, Zhang S, Zhou J (2019) Sphenopalatine neuralgia: an independent neuralgia entity. Pooled analysis of a case series and literature review. Headache 59(3):358-370
7) Hwang SH, Joo YH, Seo JH, Kim SW, Cho JH, Kang JM (2011) Three-dimensional computed tomography analysis to help define an endoscopic endonasal approach of the pterygopalatine fossa. Am J Rhinol Allergy 25(5):346-350
8) Isaacs SJ, Goyal P (2007) Endoscopic anatomy of the pterygopalatine fossa. Am J Rhinol 21:644-647
9) Kazkayasi M, Karadeniz Y, Arikan OK (2005) Anatomic variations of the sphenoid sinus on computed tomography. Rhinology 43(2):109-14
10) Lee JC, Kao CH, Hsu CH, Lin YS (2011) Endoscopic transsphenoidal Vidian neurectomy. Eur Arch Otorhinolaryngol 268:851-856
11) Levine H (1978) The sphenoid sinus, the neglected nasal sinus. Arch Otolaryngol 104:585-587
12) Marshak T, Yun WK, Hazout C, Sacks R, Harvey RJ (2016) A systematic review of the evidence base for Vidian neurectomy in managing rhinitis. J Laryngol Otol 130(Suppl. 4):S7-S28
13) Mato D, Yokota H, Hirono S, Martino J, Saeki N (2015) The Vidian canal: radiological features in Japanese population and clinical implications. Neurol Med Chir (Tokyo) 55(1):71-76
14) Mohebbi A, Rajaeih S, Safdarian M, Omidian P (2017) The sphenoid sinus, foramen rotundum and Vidian canal: a radiological study of anatomical relationships. Braz J Otorhinolaryngol 83(4):381-387

15) Omami G, Hewaidi G, Mathew R (2011) The neglected anatomical and clinical aspects of pterygoid canal: CT scan study. Surg Radiol Anat 33:697-702

16) Sadjadpour K (1975) Postfacial palsy phenomena: faulty nerve regeneration of ephaptic transmission? Brain Res 95:403-406

17) Shi J, Chen J, Chen T, Xu X, Jia Z, Ni L, Zhang Y, Shi W (2018) Neuroendoscopic resection of trigeminal schwannoma in the pterygopalatine/infratemporal fossa via the transnasal perpendicular plate palatine bone or transnasal maxillary sinus approach. World Neurosurg 120:e1011-e1016

18) Stokovic N, Trkulja V, Dumic-Cule I, Cukovic-Bagic I, Lauc T, Vukicevic S, Grgurevic L (2016) Sphenoid sinus types, dimensions and relationship with surrounding structures. Ann Anat 203:69-76

19) Su WF, Liu SC, Chiu FS, Lee CH (2011) Antegrade transsphenoidal vidian neurectomy: short-term surgical outcome analysis. Am J Rhinol Allergy 25(6):e217-220

20) Terra ER, Guedes FR, Manzi FR, Boscolo FN (2006) Pneumatization of the sphenoid sinus. Dentomaxillofac Surg 35:47-49

21) Wan-Fu S, Shao-Cheng L, Feng-Shiang C, Chia-Hsuan L (2011) Antegrade transsphenoidal Vidian neurectomy: short-term surgical outcome analysis. Am J Rhinol Allergy 25(6):e217-e220

22) Wen-Sen L, Sheng-Yao C, Yuan-Yung L, Pei-Lin Y, Hung-Che L, Li-Hsiang C, Jinn-Moon Y, Jih-Chin L (2017) Clinical assessment of diode laser-assisted endoscopic intrasphenoidal Vidian neurectomy in the treatment of refractory rhinitis. Lasers Med Sci 32:2097-2104

23) Xue Z, Liu J, Bi ZY, Bao SD, Liu PN, Yang ZJ (2019) Evolution of transmaxillary approach to tumors in pterygopalatine fossa and infratemporal fossa: anatomic simulation and clinical practice. Chin Med J 132(7):798-804

24) Yazar F, Cankal F, Haholu A, Kilic C, Tekdemir I (2007) CT evaluation of the Vidian canal localization. Clin Anat 20(7):751-754

25) Yeh IK, Wu IS (2013) Computed tomography evaluation of the sphenoid sinus and the Vidian canal. B-Ent 9:117-121

26) Yushkevich PA, Piven J, Hazlett HC, Smith RG, Ho S, Gee JC, Gerig G (2006) User-guided 3D active contour segmentation of anatomical structures: significantly improved efficiency and reliability. Neuroimage 31:1116-1128

27) Zhang H, Micomonaco DC, Dziegielewski PT, Sowerby LJ, Weis E, Wright ED (2015) Endoscopic Vidian neurectomy: a prospective case series. Int Forum Allergy Rhinol 5(5):423-430

Legend to figures

Fig. 1: example of different types of Vidian nerve protrusion according to Yeh and Wu [22]: a) type 1: Vidian nerve inside the sphenoid corpus; b) type 2, Vidian nerve partially protruding into the sphenoid sinus; c) type 3: Vidian nerve entirely protruding into the sphenoid sinus through a stalk

Fig. 2: segmented 3D model of sphenoid sinuses through ITK-SNAP software [23]: A: anterior; P: posterior; R: right; L: left

Figure 1

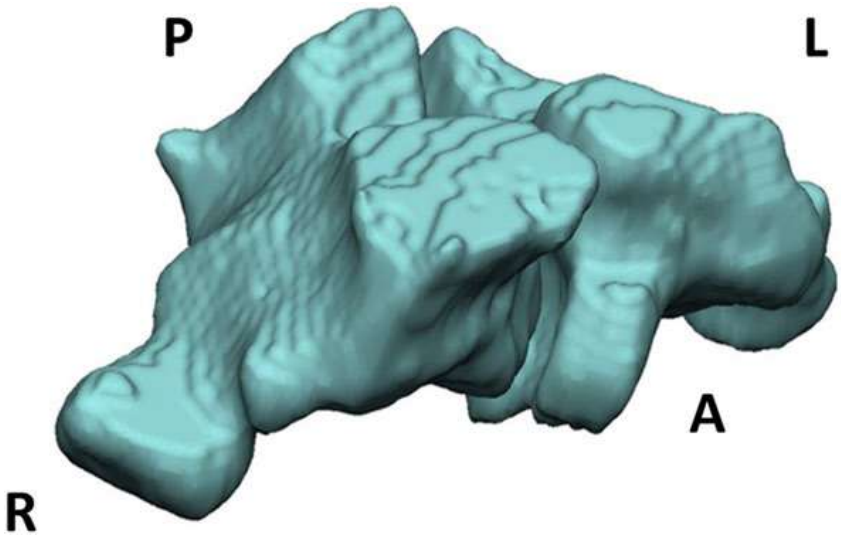

Figure 2

			Males	Females
Type 1	Prevalence (%)		43.1	34.4
	Volume (cm^3)	Mean	7.4	5.6
		SD	4.3	2.3
Type 2	Prevalence (%)		41.3	51.9
	Volume (cm^3)	Mean	10.7	9.2
		SD	3.6	2.8
Type 3	Prevalence (%)		15.6	13.8
	Volume (cm^3)	Mean	15.1	11.2
		SD	4.2	2.3

Table 1: prevalence of different types of Vidian canal protrusion, mean volume and standard deviation (SD) of sphenoid sinuses in males and females.

Authors	Population	N° of subjects	Type 1 (%)	Type 2 (%)	Type 3 (%)
Acar et al. [1]	Turkish	250	55.6	34.8	9.6
Mohebbi et al. [14]	Iranian	100	24.0	48.0	28.0
Omami et al. [15]	Libyan	300	38.3	39.6	22.0
Yazar et al. [24]	Turkish	150	36.0	54.0	10.0
Present study	Italian	320	38.8	46.6	14.7

Table 2: prevalence of Vidian canal protrusion according to different authors and populations: type 1: no protrusion; type 2: partial protrusion; type 3: complete protrusion.

	Advantages	**Disadvantages**
Transmaxillary approach	-extradural approach (reduced risk of infections and cerebrospinal fluid leakage) -shortest path to reach pterygopalatine fossa and the Vidian nerve	-possible risk of impairment of nasal cavity heating and humidification (due to the removal of the middle turbinate) -requests familiarity with anatomy and possible variants of the cranium -narrow surgical field
Transsphenoidal approach	-extradural approach (reduced risk of infections and cerebrospinal fluid leakage) -no need for sphenopalatine artery ligation -less risk of violation of the pterygopalatine ganglion -highly precise nerve cut in Vidian neurectomy	-the type of procedure depends upon the anatomical characteristics of the pterygoid canal -risk of incomplete resection due to accidental cauterization -requests high surgical skills

Table 3: advantages and disadvantages of the transmaxillary and transsphenoidal approaches to the Vidian neurectomy