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ORIGINAL RESEARCH

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The anatomy of the foramina and efferent nerve fibers from the pterygopalatine ganglion in posterolateral nasal wall

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Abstract

Background: The advance of endoscopic surgery has enabled selective section of the postganglionic nerve branches from pterygopalatine ganglion (PPG) as a modification of the vidian neurectomy. Recent microanatomic studies have suggested that the nasal mucosa is also innervated by multiple efferent rami associated with the sphenopalatine artery (SPA) in the procedure "posterior nasal neurectomy." This anatomic cadaveric study aims to identify all postganglionic nerve fibers in the lateral nasal wall which should inform future surgical procedures aimed at interrupting these nerve fibers.

Methods: Two cadaver heads, with a total of three individual sides, were dissected. All neurovascular structures penetrating the vertical plate of palatine bone were carefully identified following meticulous removal of the overlying mucosa layers. The efferent nerve fibers were identified and dissected back to their origin—the PPG or greater palatine nerve.

Results: Several foramina with efferent PPG nerves were identified on the vertical plate of the palatine bone and medial pterygoid plate. The superior, middle, and inferior turbinates (IT) were innervated by efferent nerves from the PPG via the anterior region of the SPA. The IT was innervated from nerves originating from behind the SPA through bony foramina. The lateral wall of inferior meatus was innervated by efferent nerves that originated from greater palatine nerve and pharyngeal nerve.

Conclusion: This study demonstrated the anatomical positions of the postganglionic nerves that innervate the lateral nasal wall. These nerves are located anterior to the SPA as well as posterior to the SPA, where they penetrate the palatine bone.

Level of evidence: NA.

KEYWORDS
posterior nasal neurectomy, pterygopalatine ganglion, vidian neurectomy

1 | INTRODUCTION

The term vasomotor rhinitis was coined in the 1950s to describe patients with nonallergic rhinitis and was thought to be caused by an over-reactivity of the parasympathetic (postganglionic) innervation of the nasal cavity. In the 1960s, vidian neurectomy (VN) was popularized by Goldingwood but lost popularity due to a recurrence of symptoms at about 2 years post-neurectomy as well as the high incidence of dry eye. Goldingwood's initial description for VN was for intractable vasomotor rhinitis via a trans-antral approach in 1961.[1] Recent literature suggests that VN may also be indicated for allergic rhinitis, chronic sinusitis with nasal polyps, and chronic cluster headaches.[2,3] Although VN has been reported to provide a good surgical outcome for the control of rhinitis, the surgery has risks of a dry eye and numbness in the palate and cheek.[4] Recent studies have suggested that these complications may be avoided by a selective posterior nasal nerve section. Posterior nasal neurectomy (PNN) as a selective form of VN has been reported by a number of surgeons with encouraging results.[5–7] Understanding the anatomy of the postganglionic parasympathetic and sympathetic fibers to the lateral nasal wall, which are responsible for nasal tone and secretions, may help the understanding of the tendency for symptoms to return after PNN.[8]

The anatomy of the Vidian nerve is well described with the greater petrosal nerve and deep petrosal nerve joining to form the nerve of the pterygoid canal before proceeding forward to reach the pterygopalatine ganglion (PPG) located in posterosuperior part of the pterygopalatine fossa. The sympathetic fibers of deep petrosal nerve and sensory fibers from the maxillary nerve pass through the PPG without synapse. On the other hand, the parasympathetic fibers of greater petrosal nerve originate from the superior salivary nucleus and synapse at the PPG, then merge with sympathetic fibers and sensory fibers.[9] The nerves from PPG are formed by these three different fibers and control vasoconstriction and mucosal gland secretion in the nasal cavity and palatal mucous membrane. Classically the Vidian nerve is resected where it enters the pterygopalatine fossa, while the posterior nasal nerves are resected with section of the sphenopalatine artery (SPA) and by raising the mucosal flap below and posterior to the SPA.

The aim of this study was to describe in detail the anatomy of the PPG innervation of the lateral nasal wall and floor of the nose.

2 | MATERIALS AND METHODS

Three sides of two formalin-fixed human cadaver heads donated for medical education were included in this study under the approval of the Human Research Ethics Committee of the University of Adelaide Medical School Anatomical Department. All donors completed a consent form while they were still living. Red-colored silicone was injected into the vessels of those specimens to visualize SPA.[10–12] The dissections were performed with microscope and microsurgical instruments by single dissector (Kazuhiro Ogi) to identify the peripheral branches of PPG. The cadaver heads were then cut in the midline in the sagittal plane by using a band saw, and the nasal cartilage/boney septum, free edge of inferior turbinate (IT) and middle turbinate

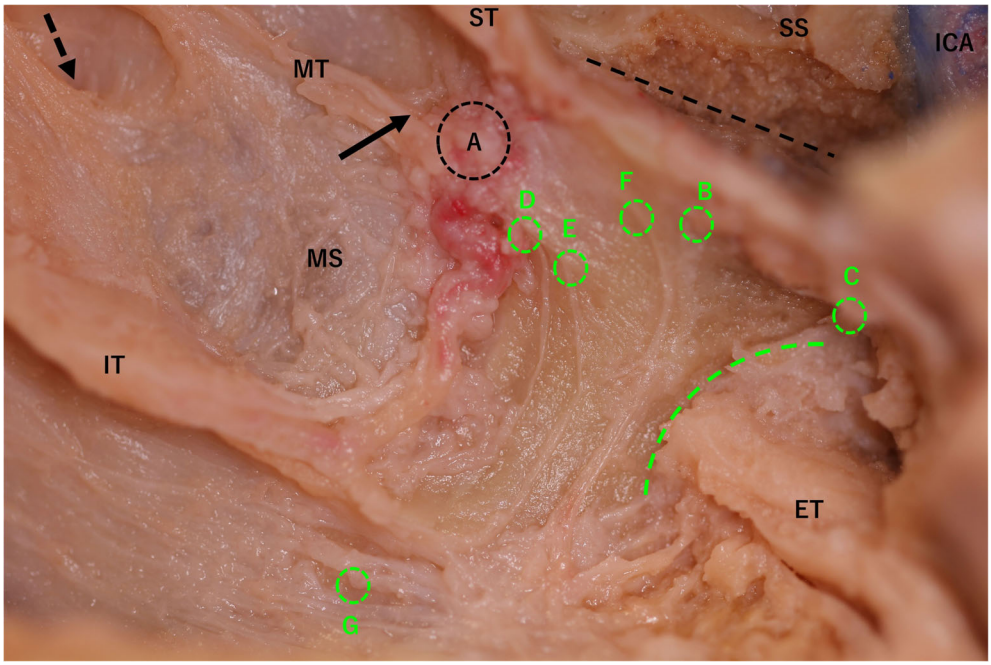

FIGURE 1 The foramina containing efferent pterygopalatine ganglion fibers on the vertical plate of the palatine bone. Cadaver dissection on the right side. The sphenopalatine artery (red silicon injected) is shown coming out of sphenopalatine foramen (black dot circle); SPA foramen (A) behind the ethmoid crest (black arrow). Broken black arrow indicates natural ostium of maxillary sinus. Vidian nerve was seen under the black dotted line and the pterygopharyngeal sulcus under the green dotted line. ET, eustachian tube; IT, inferior turbinate; MS, maxillary sinus; MT, middle turbinate; PCA, paraclival carotid artery; SS, sphenoid sinus; ST, superior turbinate.

(MT) were resected. The SPA was identified behind the ethmoid crest. The mucosa of the posterior end of the MT and lateral wall was meticulously removed layer by layer to expose any neurovascular branches that penetrated through the lateral wall of the nose to supply the nasal mucosa. Once identified, these nerves were traced back to confirm their origin. The images were taken by a digital camera (EOS 60D, Canon) with Macro Ring Lite (MR-14EX, Canon).

3 | RESULTS

3.1 | The foramina relating to PPG on the vertical plate of the palatine bone and medial pterygoid plate

A number of foramina were identified and were common to all three dissected heads. These were found on the vertical plate of the palatine bone and medial pterygoid plate. In Figure 1, the sphenopalatine foramen (SPF) is foramen A behind the ethmoid crest. The next common foramen B was found posterior to SPF under the floor of sphenoid sinus (foramen B in Figure 1). The exit of palatovaginal canal (PVC) was located at the apex of pterygopharyngeal sulcus, an inverted U-shape sulcus on the medial pterygoid plate (foramen C in Figure 1). Two further foramina were identified behind the SPF; the first foramen was found just behind the posterior edge of the SPF, then second foramen was found behind and inferior to first foramen (foramina D and E in Figure 1). Another foramen F was identified between SPF and foramen B (foramen F in Figure 1). Last foramen was found under the IT on the extension line of greater palatine nerve (Figure 1G). All foramina except for foramen D were identified in all three specimens, while foramen D was identified in two of the three specimens.

3.2 | The nerves penetrating the vertical plate of the palatine bone and medial pterygoid plate innervating nasal lateral wall

The IT, MT, and superior turbinate (ST) were mainly innervated by the efferent PPG fibers coming out anterior to the SPF (Figure 2A). The nerve bundles from foramen B descended or headed posteriorly, then ran horizontally in a superficial layer and innervated pharyngeal orifice of Eustachian tube (ET; Figure 2B). Several glossopharyngeal nerve fibers originated from behind ET and merged with nerve F below the

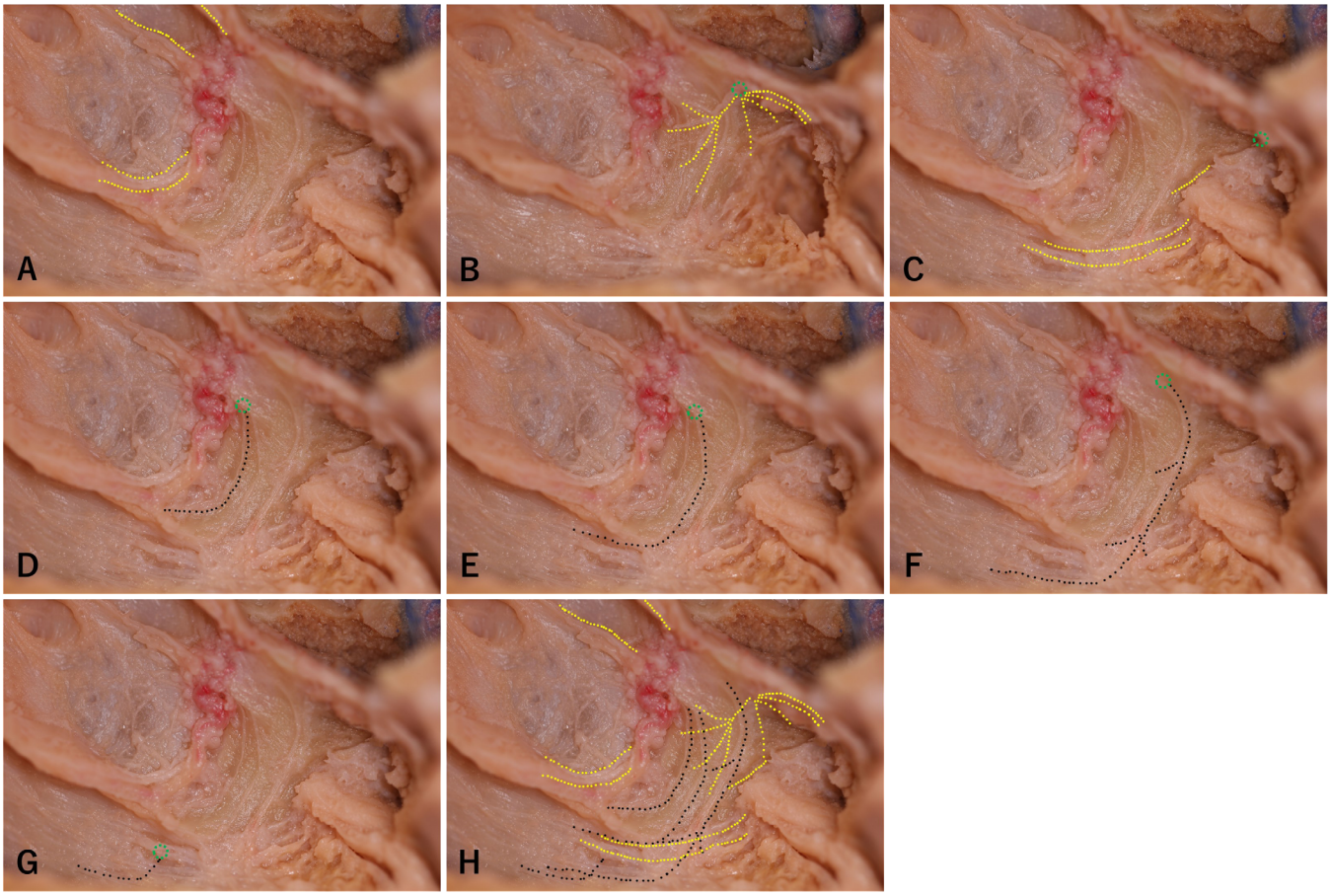

FIGURE 2 The nerves penetrating vertical plate of the palatine bone and innervating nasal lateral wall. The superficial nerve fibers ran horizontally innervating superior, middle, and inferior turbinate (A–C). The other nerve fibers ran on the vertical plate of the palatine bone penetrating the bone (D–G). The identified nerves were merged and shown in (H). Green dotted circles indicate the foramina in the bone. Yellow dotted lines indicate the nerve fibers in the superficial layer and black dotted lines indicate the nerve fibers in the deep layer.

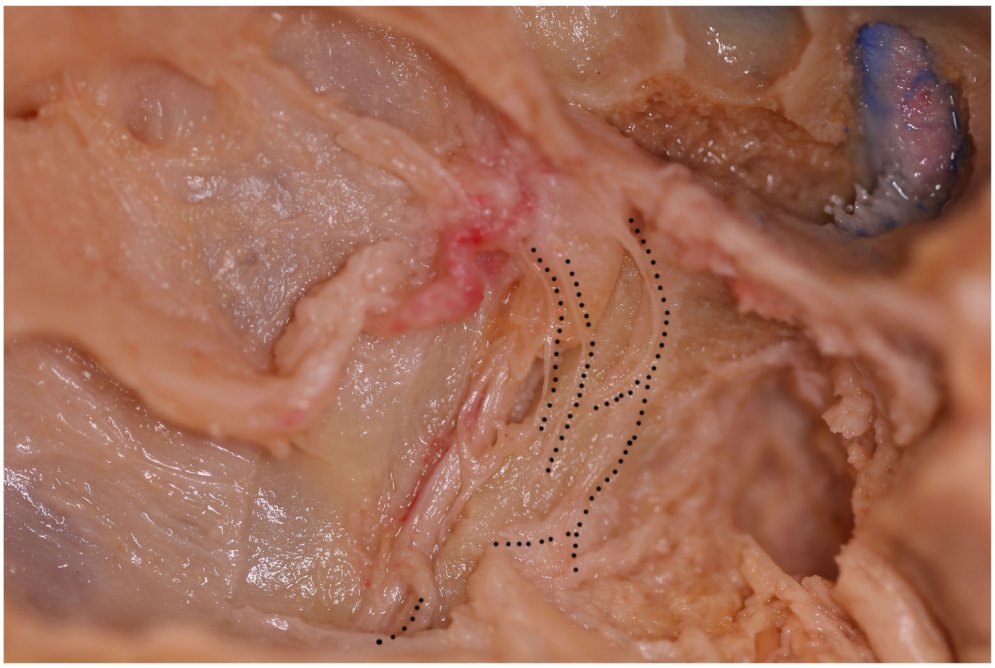

FIGURE 3 The origin of efferent postganglionic nerve fibers innervating nasal lateral wall. The cortical bone surface of the vertical plate of the palatine bone was partially removed to expose the nerve fibers innervating nasal lateral wall. Black dotted lines indicate the nerve fibers shown in Figure 2D–G.

posterior edge of IT (Figure 2C). These three nerves ran in the superficial layer of the mucosa horizontally.

The nerve originating from foramen D ran inferiorly in a groove in the vertical plate of the palatine bone and then turned forward to join with the branches from the SPA to the IT. This nerve was not identified in one of three specimens (Figure 2D). The nerve exiting through foramen E ran parallel to nerve D until the back end of the IT where it ran anteriorly under the IT (Figure 2E). The nerve from foramen F ran along with the vessels on the groove of the vertical plate of the palatine bone and gave off several branches which ran anteriorly both over and under the IT (Figure 2F). A posterior branch of nerve F ran toward to uvula joining with a pharyngeal nerve. The nerve exiting foramen G initially descended vertically with a vessel, then ran anteriorly and innervated the lateral wall in the inferior meatus under the IT (Figure 2G). The area was also innervated by a pharyngeal branch of the glossopharyngeal nerve.

Nerves D–G were followed through the foramina into the PPF by removing cortical bone (Figure 3). These nerve fibers were traced back into the PPF and then into the PPG. While nerves D–F originated from the PPG, nerve G was found to originate from greater palatine nerve (Figure 3).

In summary, the ST and MT were innervated by nerves from the region anterior to the SPA, while the IT was innervated by nerves both from the anterior SPA region and from nerves from the region behind the SPA. In addition, the mucosa of the posterolateral nasal wall was also found to be innervated by efferent PPG fibers from the PVC and glossopharyngeal nerve, as found by other authors.[13,14]

4 | DISCUSSION

This anatomical study details the rich network of postganglionic nerves originating from the PPG that are present on the lateral wall of the nose anterior to the ET and posterior to the posterior ends of the ST, MT, and IT. The posterior ends of the ST and MT receive most of their PPG nerve fibers through the anterior region of the SPF, whereas the inferior turbinate receives branches from this region as well as branches from the foramina posterior to the SPF. There are between 3 and 4 bony foramina posterior to the SPF that transmit PPG nerve fibers that form this rich network of nerves behind the turbinates that then run anteriorly suppling both the turbinates and the lateral nasal wall with PPG fibers. This network is augmented by branches coming from the PPG nerve fibers running through the PVC and from nerve fibers coming from the glossopharyngeal nerves supplying the soft palate. In addition, previous studies have shown that PPG nerve fibers track with the anterior ethmoidal nerve supplying the anterior region of the lateral nasal wall.[15]

The accessory ostia posterior to the SPF have previously been described but their precise location and relative positions are still unclear.[16] It was also interesting to see that branches were also given off by the descending palatine nerve and from the PVC (Figures 2G and 3). These posterior nerves from the PVC and glossopharyngeal nerve contain parasympathetic fibers and sensory fibers.[17,18] The IT was innervated by multiple nerves, but it is unclear whether this region generates more secretions than other regions within the nasal cavity and lateral nasal wall (Figure 2H).

Traditional surgery to control the secretion of mucous in the nasal cavity, such as a VN, has shown effectivity in controlling symptoms but include side effects due to the non-selective autonomic denervation of the PPG. These include a dry eye and crusting in the nose. However, these side effects appear to be temporary with compensation through other mechanisms ultimately restoring the reduced tear flow with improvement in symptoms associated with a dry eye.[19] Selective interruption of the efferent PPG nerve, including PNN, has shown improved outcomes with a minimum of complications. While PNN as it is currently described (section of the SPA and nerves shown in Figure 2A after lifting of the mucosal flap posterior and inferior to the SPF) may address a

proportion of the parasympathetic innervation of the lateral nasal wall, a significant number of nerve fibers would remain which could explain the temporary nature of the symptom improvement after this procedure. Care should be taken not to damage the descending palatine and branches from the glossopharyngeal nerve as this may result in palatal paresthesia. During PNN, division of the SPA is also controversial with some surgeons recommending it and others not.[20,21] Failure to divide the SPA may result in the preservation of a significant number of PPG nerve fibers that run with the vasculature.

The limitations of this study are insufficient number of specimens and lack of histological analysis. Further study compensating for these factors would contribute to the development of better surgical intervention.

5 | CONCLUSION

The cadaveric dissections were conducted to enhance the anatomical understanding of efferent PPG nerves. This study supports visual understanding of the complex postganglionic innervation of the posterolateral nasal wall. Ultimately it is hoped that such a study will improve the surgical outcomes of procedures aimed at disrupting the postganglionic parasympathetic nerve innervation in the management of intractable vasomotor rhinitis and allergic rhinitis.

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CONFLICTS OF INTEREST

PJW is a consultant for Neurent. PJW and AJP are currently involved in a funded research trial for Neurent. The other authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

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