

## Review Article

# Greater superficial petrosal nerve and its surgical importance: a review

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### ABSTRACT

The greater superficial petrosal nerve (GSPN) is an important but often underappreciated branch of the facial nerve. The GSPN is a mixed nerve which contains both sensory and parasympathetic fibers. It serves as the motor root of the pterygopalatine (sphenopalatine) ganglion. GSPN has a long course which passes across the middle skull base between the petrous bone and dura mater and running through the foramen lacerum. It then incorporates to the deep petrosal nerve and crosses along the pterygoid canal to the pterygopalatine ganglion. The postganglionic nerve fibers innervates the lacrimal glands, nasal mucosa and palatal mucosal glands via branches of the zygomatic nerve/zygomaticotemporal branch, sphenopalatine, greater palatine, lesser palatine nerves and pharyngeal nerve. Surgical anatomy of the GSPN nerve is often unfamiliar to many clinicians. As this nerve is usually unrecognized without use of high resolution microscope or endoscope, its anatomical knowledge is essential for surgeons basically otologists and other head and neck surgeon to minimize the risk of injury during surgical intervention. This review article surely increases the precise knowledge of the GSPN including its embryology, surgical anatomy, blood supply, relations with other structures and imaging.

**Keywords:** Greater superficial petrosal nerve, Facial nerve, Geniculate ganglion, Schwannoma

### INTRODUCTION

The greater superficial petrosal nerve (GSPN) or greater petrosal nerve (GPN) is a branch of the nervus intermedius (nerve of Wrisberg) which carries the parasympathetic fibers, nerve fibers for taste and sensory fibers of the facial nerve (CN VII).<sup>1</sup> The GSPN arises from the geniculate ganglion (GG) of the facial nerve and courses antero-medially to leave the superior surface of the temporal bone through the GSPN hiatus. The GSPN innervates the lacrimal glands and mucous membrane of the nasal cavities and the palate as major secretory fibers.<sup>2</sup> Although the pathological lesions like schwannoma are uncommon in GSPN in comparison to the facial nerve, the surgical approach for this nerve is usually done with caution as many surgeons are not much

familiar with anatomy of GSPN. The transaction of the GSPN is done as vidian neurectomy for pathologies like intractable chronic vasomotor headache and severe rhinitis.<sup>3</sup> Many previous studies described the certain part of the GSPN. The whole course of the GSPN from origin at the geniculate ganglion to its end at the pterygopalatine ganglion has rarely been described in medical literature. Lesions of the GSPN are also infrequently documented and also many clinicians or surgeons are not well versed with this nerve.

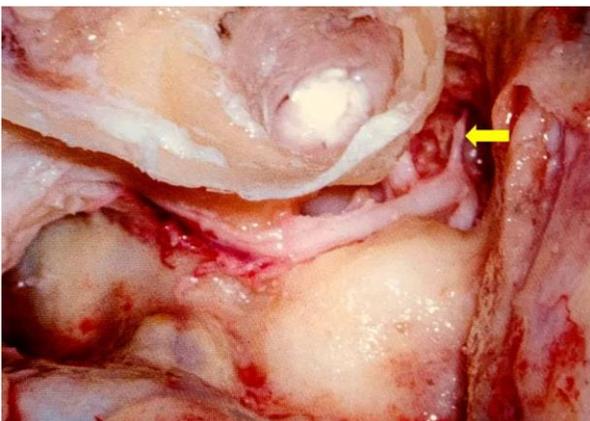
This review article is aimed to describe details of the course of the GSPN, its surgical importance, embryology, blood supply, lymphatic drainage, pathological lesions, imaging and its relationship with surrounding landmarks.

## METHODS OF LITERATURE SEARCH

Research articles regarding greater superficial petrosal nerve were searched through multiple approaches. First, we conducted an online search of the PubMed, Scopus, google scholar and Medline database with the word greater superficial petrosal nerve, greater petrosal nerve, facial nerve, surgical anatomy, embryology, blood supply and surgical importance of the GSPN. The abstracts of the published articles were identified by this search method and other articles were identified manually from the citations. This review article reviews the surgical anatomy, anatomical relationship with other bony landmarks, embryology, blood supply, lymphatic drainage, different injuries of the GSPN and surgical importance of the GSPN. This review article presents a baseline from where further research for this nerve can be designed and also help as a spur further research in this nerve where not many studies are done. The objective of this review article is to provide a precise and brief knowledge regarding the GSPN and its surgical importance.

## SURGICAL ANATOMY

GSPN is the first branch of the facial nerve which arises from the geniculate ganglion.<sup>4</sup> It carries both parasympathetic and sensitive fibers and it merges in the middle cranial fossa occupying the facial hiatus. It innervates the lacrimal glands, mucosal linings of the nasal cavity and palate.<sup>4</sup> The nerve fibers which form the greater petrosal nerve arise from the lower part of the pons. This nerve is called as a mixed nerve because of its both sensory and parasympathetic nerve fibers. The main bulk of the greater petrosal nerve is sensory component which arise from the facial nerve. This parasympathetic component exits from the brain stem as a separate nervous intermedius. From the geniculate ganglion, the GSPN (Figure 1) courses antero-medially and exit through the hiatus for this nerve at superior surface of the temporal bone.



**Figure 1: Surgical specimen of origin of the greater superficial petrosal nerve from the geniculate ganglion of the facial nerve.**

The pre-ganglionic parasympathetic fibers arise from the superior salivatory nucleus of tractus solitarius at the pontine tegmentum and progress in the nervus intermedius before joining to the facial nerve.<sup>5</sup> These nerve fibers transverse the geniculate ganglion without synapsing and exit the ganglion anteriorly as the GSPN.<sup>6</sup> The GSPN runs antero-medially and leaves the superior surface of the temporal bone via the hiatus of the greater petrosal nerve (hiatus fallopii/facial hiatus) and into the middle temporal fossa.<sup>7</sup> In the facial hiatus, this nerve runs alongside the middle meningeal artery. The greater petrosal nerve passes the floor of the middle temporal fossa, medially to the lesser petrosal nerve and laterally to the internal carotid artery, antero-medially and slightly inferiorly running beneath the Gasserian ganglion in Meckel's cave and forwards towards the foramen lacerum and the pterygoid canal.<sup>6</sup> The petrosal segment of the internal carotid artery (ICA) is usually coursed below the GSPN, with a very thin bony lamella separating them; however, near the foramen lacerum, this thin bony separation absent in 70.25% of the cases.<sup>8</sup> Then this nerve courses antero-medially and slightly inferiorly and passes under Meckel's cave towards the foramen of lacerum where it joins with the deep petrosal nerve from carotid sympathetic plexus and these together form vidian nerve.<sup>9</sup>

GSPN runs antero-medially along the middle fossa floor and forms the medial border of the Kawase triangle. It lies in the major petrosal groove and covered with a layer of connective tissue. The connective tissue is continuous with the periosteum as periosteal dura mater. At the middle fossa, the GPN courses within the inter-dural space of the temporal lobe between the meningeal dura mater and periosteal dura mater.<sup>10</sup> Some authors divide the GSPN into four segments such as intra-petrosal segment running from geniculate ganglion to facial hiatus; supra-petrosal segment running from the hiatus to the foramen lacerum; the segment of the foramen lacerum and the segment of the pterygoid canal.<sup>11</sup> In relation to the trigeminal ganglion, the supra-petrosal segment may be divided into two parts such as outer segment and posterior segment. At the proximal part of the pterygoid canal, the GSPN join to the deep petrosal nerve, making the nerve of pterygoid canal or vidian nerve.<sup>12</sup> At this point, the vidian nerve carries pre-ganglionic, taste and sensory fibers from the greater petrosal and postganglionic sympathetic fibers from the internal carotid plexus through the deep petrosal nerve. The vidian nerve runs anteriorly through the pterygoid canal to the pterygopalatine fossa.<sup>7</sup> The sympathetic fibers of the deep petrosal nerve cross the pterygopalatine fossa without synapsing and gives rise to all branches of the maxillary division of the trigeminal nerve (V2) with innervations of the sympathetic fibers. The postganglionic parasympathetic fibers proceed to give secretory and vasomotor innervations to the lacrimal glands, nasal and palate mucosal linings.<sup>13</sup>

The important landmarks include petrous segment of the ICA and the cochlea. The ICA is related laterally under

GSPN. The cochlea is situated just medial to the geniculate ganglion of the facial nerve and 9 mm from the head of the malleus and 2 mm from the genu of the petrous ICA.<sup>14</sup> Anatomically, schwannomas may arise from the GSPN at middle cranial fossa.

### **ANATOMICAL RELATIONSHIP OF GSPN**

The anatomical relationship of the facial nerve and its branches are well known in the literature. There may be variations in the distance from the bony landmarks to the GSPN. However, there are not many studies are done about the bony anatomical landmarks in respect to the GSPN. Bony structures are favorable landmarks than soft tissues for finding the reliable location for GSPN.<sup>15</sup> The vidian nerve is formed by the GSPN and deep petrosal nerve. The formation of the vidian nerve is at the cartilaginous substance which fills the foramen lacerum. From this place, it runs forward through the pterygoid canal accompanied with artery of the pterygoid canal. GSPN is visible in MRI in healthy persons if the radiologist is familiar with the anatomy.<sup>16</sup>

The anatomical landmarks is basic and very vital to the surgeons and radiologists before and during the surgical intervention. One study shows distance between superior petrosal sinus to middle hiatus for the greater petrosal nerve is 13 mm.<sup>17</sup> The distance from lateral margin of middle cranial fossa to middle hiatus for the GSPN is 25mm and distance from arcuate eminence to hiatus for the GSPN is 19 mm.<sup>17</sup> The distance from the exit of hiatus for GSPN to foramen spinosum.<sup>17</sup> Another study showed distance between arcuate eminence to hiatus for GSPN is 17.5 mm and the distance from the hiatus for GSPN to foramen spinosum was 7 mm.<sup>13</sup> The distance between supra-petrosal part/segment of the GSPN between the foramen lacerum and leaving hiatus fallopii is  $17.30 \pm 1.48$  mm. The mean length from hiatus fallopii to the intersection point of the trigeminal ganglion and GSPN is  $11.92 \pm 1.87$  mm, and  $5.54 \pm 1.29$  mm from the foramen lacerum.<sup>8</sup> The mean diameter of this segment of GSPN is  $0.44 \pm 0.08$  mm.<sup>8</sup>

The foramen lacerum segment of the GSPN extends from the point of entering foramen lacerum to its entrance into the pterygoid canal. In this segment, the length of the GSPN is  $9.29 \pm 1.88$  and mean diameter  $0.60 \pm 0.11$  mm.<sup>8</sup> This segment of GSPN has a close relationship with sympathetic nerve and ICA. In the foramen lacerum the GSPN run antero-superiorly toward the posterior opening of the pterygoid canal. The pterygoid canal segment is also called as pterygoid canal nerve or vidian nerve which extends from the pterygoid canal/vidian canal to the pterygopalatine ganglion. The length of the pterygoid canal segment of the GSPN is  $17.79 \pm 1.09$  mm with mean diameter of  $0.88 \pm 0.11$  mm.<sup>8</sup> The middle fossa approach involves a temporal craniotomy in case of perineural spread of adenoid cystic carcinoma; so these anatomical landmarks in relation to GSPN will help as a useful guide for the surgeons and radiologists.

### **EMBRYOLOGY**

After third week of intrauterine period, a group of neural crest cells found at the metencephalon rostral to otic placode. This neural cluster is called as the facioacoustic primorium which gives rise to the CN VII and CN VIII. At the fourth week of the intrauterine period, facial and acoustic parts are better defined and the facial section ending at the epibranchial placode on the second branchial arch.<sup>18</sup> The GSPN may be found during 5 to 6 weeks of embryogenic development rostral to geniculate ganglion. It is well defined by the 8th week which joins with the deep petrosal nerve adjacent to the internal carotid artery to form the vidian nerve. Then it terminates into group of the neural crest cells which will form the pterygopalatine ganglion.<sup>19</sup>

### **BLOOD SUPPLY AND LYMPHATIC DRAINAGE**

The blood supply of the GSPN is by middle meningeal artery and artery of pterygoid canal, arise from the maxillary artery. These two branches of the maxillary artery communicated in the area of foramen lacerum. The GSPN get blood supply by the superficial petrosal branch of the middle meningeal artery which anastomosis with stylomastoid branch of the posterior auricular artery and the artery of the pterygoid canal.<sup>20</sup>

The middle meningeal artery gives blood supply to the intra-petrosal segment, supra-petrosal segment and segment of foramen lacerum of GSPN in three patterns. In type-A pattern, the artery supply both the GSPN and lesser petrosal nerve, arising from the trunk distal to the foramen spinosum in 42.5% cases. In type-B, the artery supplies GSPN and lesser petrosal nerve arising from the trunk in 20% cases.<sup>8</sup> In type-C, the artery arise from the trunk of middle meningeal artery outside of the skull, run through the foramen ovale and bifurcated to supply the lesser petrosal nerve in 12.5% cases.<sup>8</sup> The lesser petrosal nerve travel through the floor of the middle fossa inferior to the GSPN. The venous drainage of the GSPN is to the superior petrosal vein. The lymphatics of the GSPN is to the lymphatic system of the skull, however the details of this remains unknown.

### **INJURIES OF THE GSPN AND CLINICAL MANIFESTATIONS**

Due to the smaller size, longer course, improper osseous protection and slim artery blood supply, the GSPN is prone for injury at the time of surgical dissection. The anatomical course of GSPN and its pathological lesions must be known to the clinicians. The injuries of the GSPN are usually caused by the tumors, skull base fractures and during surgical procedures.<sup>21</sup>

Understanding of the entire course of the GSPN and its anatomical relations with neurovascular structures are important during performing the surgical procedures such as transaction of the GSPN particularly in surgery of the

skull base area. The injury of the GSPN can also be avoided with proper understanding of the normal and varied course of the nerve. Injury of the GSPN results in xerotic keratitis. Patient with injury of the GSPN may present with xerophthalmia, corneal ulcer and also potential for blindness.<sup>22</sup> If the traction is applied to the geniculate ganglion or manipulation of the GSPN can cause facial nerve injury and facial palsy.<sup>23</sup>

## **SURGICAL IMPORTANCE**

GSPN innervates the lacrimal glands and mucous membranes of the nasal cavity and palate. There are several pathological lesions associated with GSPN. Vasomotor rhinitis is a clinical condition where patient present with sneezing, profuse rhinorrhea and nasal obstruction which may be perennial or paroxysmal. 24Activation of the parasympathetic or interruption of the sympathetic nerve fibers to the mucosal membrane of the nasal wall causes vasodilatation, sneezing and hypersecretions. The exact anatomical landmark for the GSPN helps the surgeon to perform the vidian neurectomy as the treatment option in vasomotor rhinitis. Schwannoma may arise from the GSPN and it is an uncommon type of the facial nerve schwannoma which constitutes 0.8% of all the petrous bone lesions.<sup>25</sup> The schwannoma of the GSPN was first described by Woodruff et al. in 1981.<sup>26</sup>

As the GSPN contains the parasympathetic nerve fibers to the lacrimal gland, reduced tear secretion is an important clue for diagnosis of the GSPN schwannoma.<sup>27</sup> The common clinical presentations of the GSPN schwannoma are facial nerve palsy, hearing disturbances due to destruction of the inner ear, headache and redness and burning pain of the eye. Computed tomography (CT) scan provides bony details and shows any erosions of the petrous bone or enlargement of the internal auditory canal. The facial canal and hiatus are also better delineated by the CT scan. MRI is very useful imaging to detect the GSPN schwannomas and their relation with facial nerve. The differential diagnosis of the GSPN schwannoma includes facial nerve schwannoma, trigeminal nerve schwannoma, congenital cholesteatoma, meningioma and bony tumor of the petrous bone.<sup>26</sup>

The surgical excision of the GSPN schwannoma is through the middle fossa approach which remains the first line of treatment.<sup>25</sup> Because of the relative rarity of the GSPN schwannoma, preoperative misdiagnosis may happen unless one is aware about the clinical and radiological findings. The clinical presentations of the GSPN schwannoma depend on the size of the tumor.<sup>28</sup> The early clinical presentation of this tumor in GSPN is decreased tear secretion followed by the facial nerve palsy. The presence of the extra-axial enhancing mass at the anterior aspect of the middle part of petrous bone with underlying bony erosion along with clinical findings is helpful for early diagnosis. Early diagnosis and surgical treatment of the GSPN schwannoma may help to preserve the function of the facial and acoustic nerve.

## **IMAGING OF THE GSPN**

High resolution CT (HRCT) scan give the details of the follow up reconstructed images which can describe the anatomy of the GSPN including the relationships of the bony groove for GSPN and pterygoid canal.<sup>29</sup> HRCT is essential for preoperative evaluation of the GSPN. At the anterior superior surface of the petrous bone showing scalloping erosion in CT scan is pathognomonic of schwannoma of the GSPN in contrast to trigeminal schwannoma resulting in petrous apex erosion.<sup>30</sup>

Magnetic resonance imaging (MRI) is more useful for detecting the pathological lesions of the GSPN such as schwannomas and their relation with the facial nerve. In case of GSPN schwannomas, MRI findings include mildly hypo- or hyperintense to gray matter on T1-weighted images and hyperintense on T2-weighted images with marked contrast enhancement.<sup>31,32</sup>

The differential diagnosis of the GSPN lesions include facial nerve schwannoma, trigeminal nerve schwannoma, primary cholesteatoma, meningioma, osseous tumor of the petrous bone.<sup>33</sup> The lesions like schwannomas of the GSPN are usually treated by surgical excision through the middle fossa approach.<sup>25</sup> The middle fossa approach includes temporal craniotomy in case of perineural spread of adenoid cystic carcinoma, so the anatomical landmarks of the GSPN will help as useful guide for the radiologists and radiologist.

## **CONCLUSION**

GSPN is the first branch of the facial nerve which arises from the geniculate ganglion. It innervates the lacrimal glands and mucosal glands of the nasal cavity. Any pathological lesions in the GSPN may result in facial nerve palsy, hearing disturbances, dry eyes, headaches and diplopia. The lesions like schwannoma in the GSPN may occur, so need a high suspicion level of clinicians when dealing with patients of middle cranial fossa tumors. It is imperative to know the surgical anatomy of the GSPN for early diagnosis of the lesions in GSPN like schwannoma and to make a safe decision for surgical management of the lesions.

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