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SRS/SRT SUPPLEMENT

TECHNICAL AND ANATOMICAL ASPECTS OF NOVALIS STEREOTACTIC RADIOSURGERY SPHENOPALATINE GANGLIONECTOMY

Antonio A. F. De Salles, M.D., Ph.D.,*† Alessandra Gorgulho, M.D.,* S. Raymond Golish, Ph.D., M.D.,* Paul M. Medin, Ph.D.,† Dennis Malkasian, M.D., Ph.D.,* Timothy D. Solberg, Ph.D.,† and Michael T. Selch, M.D.†

*Division of Neurosurgery, and †Department of Radiation Oncology, David Geffen School of Medicine, University of California, Los Angeles, CA

Background: Several techniques have been applied for destruction of the sphenopalatine ganglion to control cluster headache and ocular pain with sympathetic component. Cluster headache has responded to radiofrequency ablation or phenol destruction. Radiosurgery of the sphenopalatine ganglion is promising due to the excellent visualization of the target on magnetic resonance imaging (MRI), computed tomography (CT), and skull X-rays.
Material and Methods: Six patients and one cadaver head were analyzed in this study. The cadaver-head dissection confirmed the location of the sphenopalatine ganglion on X-rays and CT imaging. One patient undergoing radiofrequency sphenopalatine ablation participated for confirmation of the location of the ganglion on plain X-rays. Five patients received radiosurgery of the sphenopalatine ganglion. One patient had classic unilateral cluster headache. Two patients had neuropathic pain and 1 had bilateral migrainous neuralgia. The fifth patient had bilateral atypical facial pain. All received a single maximal dose of 90 Gy with a 5- or 7.5-mm circular collimator. MRI, CT, and skull X-rays identified and confirmed the target.
Results: The sphenopalatine fossa is seen in the skull X-ray as an inverse tear drop just caudal to the sphenoid sinus. This location is readily correlated to the CT target by the stereotactic coordinates and confirmed with the presence of the ganglion visualized in the MRI scan. Only the patient with cluster headache experienced lasting pain relief.
Conclusion: Multiple imaging modalities confirmed the location of the sphenopalatine ganglion for radiosurgery. The procedure was performed safely with CT and MRI fusion. Radiosurgery was significantly beneficial only on classic cluster headache.

Sphenopalatine neuralgia, Facial pain, Cluster headache, Radiosurgery, Pterygopalatine fossa.

INTRODUCTION

The complexity of facial pain syndromes has lead to confusion regarding their diagnosis and surgical treatment. The use of a single destructive procedure as the only form of treatment for facial pain refractory to medication has met with disappointing results. Facial pain syndromes that do not fit the diagnosis of classic trigeminal neuralgia lack established surgical treatment. It is generally accepted that atypical facial pain, encompassing only the somatoform, does not respond to any surgical treatment (1). The other forms of facial pain, including traumatic deafferentation, postsurgical pain, postherpetic neuralgia, and pain from multiple sclerosis, lack specific treatments but do respond to ablative procedures of the trigeminal and sphenopalatine ganglia (2).

The sphenopalatine ganglion (SPG) carries sympathetic and parasympathetic components and is easily accessible by needle for blockade (3) or focused radiation (4–6). Cluster headache is known to respond to blockade of the SPG and is the prototype of autonomic-related facial pain. Therefore, stereotactic radiosurgery (SRS) with the Novalis system was used in a group of patients who had failed all prior medical and surgical management for facial pain with a burning quality and an autonomic component. This report details technical aspects of linear accelerator radiosurgery of the SPG and preliminary results of the treatment in a series of 5 patients with complex facial pain syndromes.

METHODS AND MATERIALS

Anatomic studies

The SPG was dissected on the right side of a cadaver head, the ganglion was marked with a radiopaque marker (Fig. 1), and plain X-rays (Fig. 2) and a computed tomography (CT) scan were

Reprint requests to: Antonio A. F. De Salles, M.D., Ph.D., 200 UCLA Medical Plaza, Suite 504, Los Angeles, CA, 90095-7182. Tel: (310) 267-5217; Fax: (310) 794-1848; E-mail: adesalles@mednet.ucla.edu
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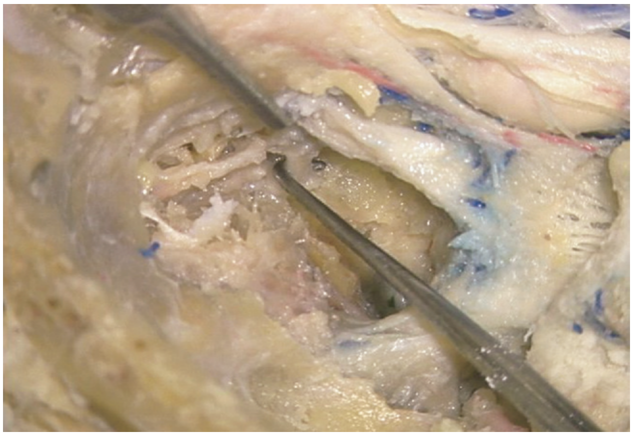

Fig. 1. View of the pterygopalatine fossa through Meckel's cave. Notice the upper retraction instrument lifting the second division of the trigeminal nerve to expose the sphenopalatine ganglion (tip of the lower instrument).

obtained (Fig. 3). Five patients undergoing SRS of the sphenopalatine ganglion had anteroposterior and lateral X-rays with the angiographic stereotactic localizer attached to the stereotactic frame on the day of treatment. These images were digitized to the Novalis Radiosurgery Software (Brain Laboratory AG, Heimstetten, Germany) and correlated with 3-mm stereotactic CT images fused to 1-mm magnetic resonance imaging (MRI) scans obtained on the same day of radiosurgery.

Patients

Five patients were treated with SRS of the sphenopalatine ganglion for facial pain or headache in the period between August 1999 and February 2004. Table 1 summarizes the clinical characteristics of these patients. All patients had undergone both previous medical management by pain specialists and prior surgical management by our neurosurgical service and other services. The patients proved to have complex and difficult facial pain syndromes that were refractory to many other therapies. All patients received SPG blockade (bupivacaine 0.5%, 2 mL) or cocainization of the nose for diagnosis before SRS. All patients reported temporary improvement of pain after diagnostic block of the sphenopalatine ganglion. Patients were counseled regarding the risks and benefits of SRS as well as alternatives. Two patients received bilateral treatment in the same sitting (Table 1).

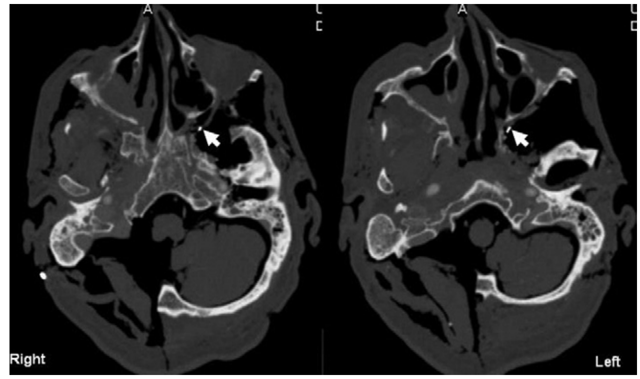

Fig. 3. Axial computed tomography cuts through the region of the sphenopalatine ganglion. The right side of each image was not dissected. The left side of each image was dissected and a radiopaque marker placed in the pterygopalatine fossa to mark the position of the sphenopalatine ganglion (arrows).

Radiosurgery technique

Patients were treated with single dose SRS using the Novalis System (BrainLAB AG). Imaging consisted of MRI with a Sigma 1.5T scanner (General Electric Medical Systems, Milwaukee, WI) and CT with an MxTwin scanner (Marconi Medical Systems, Mission Viejo, CA) or similar equipment. The same procedure used for radiosurgery of the root of the trigeminal nerve at the University of California Los Angeles was used for this study (7–9). Variation occurred only in the anatomic localization and imaging modality. Briefly, the sphenopalatine fossa was identified on plain skull X-rays, and a target was determined. The location defined on X-rays was related to the location determined on CT fused to MRI.

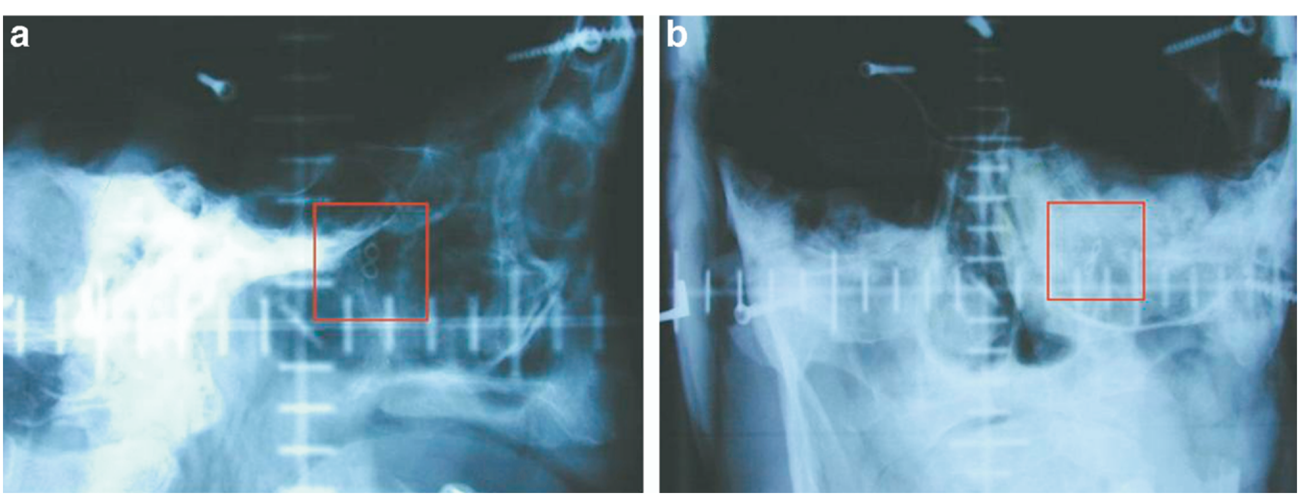

Fig. 2. (a) Right lateral X-ray of a cadaver with a radiopaque marker placed in the pterygopalatine fossa, after dissection, to mark the position of the sphenopalatine ganglion. (b) Anteroposterior X-ray of a cadaver with a radiopaque marker placed in the pterygopalatine fossa, after dissection, to mark the position of the sphenopalatine ganglion. Squares show the area of the pterygopalatine fossa with the marker.

Table 1. Characteristics of the patients treated with radiosurgery of the sphenopalatine ganglion

Patient	Age/sex	Diagnosis	Side	Prior surgical treatment
1	56 M	Posttraumatic	R	Radiofrequency ablation × 2
2	69 F	Postsurgical neuralgia	R	Radiofrequency ablation × 3
3	51 F	Migrainous neuralgia	Bilateral	Radiofrequency ablation × 1, lumboperitoneal shunt
4	38 M	Cluster headache	R	Radiofrequency ablation
5	70 M	Atypical facial pain	Bilateral	Alcohol lyses of the trigeminal ganglion

Abbreviations: F = female; M = male; R = right.

Collimators of 5-mm and 7.5-mm diameter were used with five to seven noncoplanar arcs per target to deliver 90 Gy to the center of the target in a single dose. The periphery of the target (i.e., the walls of the pterygopalatine fossa) was always encompassed by at least the 50% isodose line (Fig. 4). Table 2 presents basic parameters of the radiosurgical plans for all 5 patients. Two patients were treated with the 7.5-mm collimator; these 2 patients had extremely refractory pain with important emotional component. The larger collimator was used in a trial to maximize the possibility of good results in these 2 patients. The radiosurgery dose was delivered in 45 min per target. Patients were not admitted to the hospital and were not specifically medicated on the day of treatment, except for typical analgesics and local anesthesia at the sites of the stereotactic frame pins.

RESULTS

The dissection showed the location of the sphenopalatine ganglion in close relationship with the second division of the trigeminal nerve (V2); see retraction of V2 on dissection (Fig. 1). Despite this relationship between V2 and the SPG, patients did not report dysesthesias or numbness in the V2 territory. The pterygopalatine fossa is seen in the lateral skull X-rays as an inverse tear drop just caudal to the sphenoid sinus (Fig. 2a); the fossa is well visualized in the anteroposterior view as a cavity with a roof lateral to the nose cavity (Fig. 2b). Figure 3 shows CT images from the dissected cadaver in which a radiopaque marker was placed in the left pterygopalatine fossa; the right fossa was left intact for comparison and confirmation of the accuracy of the target selection on CT-MRI fusion. The location of the fossa on plain skull X-rays is readily correlated to the CT target by the stereotactic coordinates and confirmed with the presence of the ganglia visualized on the MRI demonstrating the dose distribution over the ganglia (Fig. 4).

Among Patients 1 through 4, only Patient 4 has experienced continued relief of facial pain and headache. This patient was treated with the 7.5-mm collimator and had the diagnosis of cluster headache. The other patients experienced temporary relief, but required further medical management (albeit with less medication) or further surgical management. Patient 1 was subsequently treated with three trials of supraorbital and infraorbital rhizolysis. Patient 2 was subsequently treated with radiofrequency ablation of the SPG and a cortical stimulator. Overall, the modest success of therapy is not surprising because these patients all have severe complex pain syndromes refractory to many attempts at treatment. Our emphasis here is on the technical aspects of the treatment. Patient 5 reported mild control of pain and required less analgesics. He was able to stop his opioid intake. The follow-up spans from 2 to 6 years; no complications from the radiation or image changes were detected in these patients.

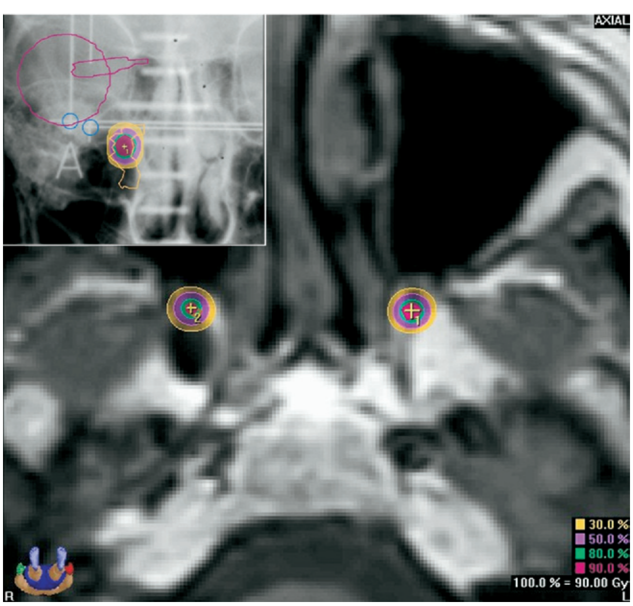

Fig. 4. Axial T1-weighted magnetic resonance imaging with isodose wash superimposed for the bilateral sphenopalatine ganglia of Patient 5. (Insert) Anteroposterior X-ray of the skull with isodose wash superimposed demonstrating the locations of the target on plain X-rays as correlated by the stereotactic coordinates.

DISCUSSION

Patient selection

All patients included in this study had facial pain and other symptoms that could be addressed with ablation of the sphenopalatine ganglion. Recognition of the role of the sphenopalatine ganglion in pain syndromes dates to the early 20th century. Sluder first described SPG neuralgia as a syndrome involving variable symptoms attributable to the sensory, sympathetic, and parasympathetic functions of the ganglion (10, 11). Classic symptoms include a burning unilateral pain of the maxillary, ocular, otic, or nasal regions possibly radiating to the neck. Pain may be accompanied by sensory changes of the mouth and palate, gustatory changes,

Table 2. Radiosurgery parameters for treatment of the sphenopalatine ganglion

Patient	Dose (Gy)	IDL (%)	Collimator (mm)	Arcs per side	Side	Time of delivery (min)
1	90	100	5	5	R	45
2	90	100	5	5	R	45
3	90	100	7.5	6	B/L	90
4	90	100	7.5	7	R	45
5	90	100	5	7	B/L	90

Abbreviations: B = bilateral; IDL = isodose line; L = left; R = right.

ocular hyperemia, or increased lacrimation. The syndrome is classically associated with rhinorrhea and nasal or sinus infection. Attacks may last minutes to days and cluster together with intervals of remittance. Awareness of SPG-related facial pain proliferated after its initial description (12). However, the classic syndrome and its relationship to similar pain syndromes continue to be controversial. Many alternative names for SPG neuralgia are in use. The original definition has been broadened to include similar syndromes without the classic features. SPG neuralgia is often compared or equated with cluster headache and other headaches (13). Clearly, there are close relationships between the various headaches and facial pain syndromes. A revised taxonomy has been proposed in which SPG neuralgia is classified as a vascular phenomenon closely related to cluster headache (14).

Patients selected for radiosurgery in this study had relief of their symptoms with a diagnostic sphenopalatine anesthetic block. Descriptions of the relief of pain by blockade of the SPG appeared early (15), and the historical aspects have been reviewed (3). Because knowledge of the procedure is now widespread (16), blockade of the SPG has been used for a variety of facial pain disorders in addition to SPG neuralgia (17, 18). These include cancer pain (19, 20), trigeminal neuralgia (18), cluster headache (21, 22), and oral pain (23). Further, SPG blockade has been recommended for pain beyond the head, including myofascial pain of the neck and shoulders (18) and the low back (24, 25). SPG blockade has even been used to treat nicotine addiction (18), stress, and psychosomatic complaints (26). Acupuncture in the SPG region has been used for trigeminal neuralgia (27, 28). The only well-established indication for SPG blockade is classic cluster headache (22). In addition to therapeutic blockade, permanent treatment of the SPG has been widely practiced. Methods include surgery (27, 29), alcohol lysis (30), radiofrequency thermoablation (2), cryotherapy (31), and stereotactic radiosurgery (4–6).

Imaging aspects

Knowledge of the *in vivo* anatomy of the sphenopalatine ganglion and pterygopalatine fossa and correlation with modern volumetric reconstruction and image fusion are keys to optimal radiosurgical planning. This study shows correlation from the anatomic specimen to high resolution MRI, taking advantage of the information of intermediate imaging techniques such as plain X-rays and CT. This study confirms borders of the pterygopalatine fossa with multiplanar imaging. The pterygopalatine fossa is open laterally and inferiorly, but is enclosed by bone on all other sides. The anterior border is the posterior wall of the maxillary sinus, and the posterior border is the medial plate of the pterygoid process of the sphenoid bone. The medial border is the perpendicular plate of the palatine bone. Finally, the roof of the fossa is formed by the sphenoid bone.

The radiographic anatomy of the fossa by CT and MRI has been reviewed (32). The walls of the pterygopalatine fossa are well visualized on CT, and the contents of the fossa are well visualized on MRI; therefore, these two modalities are essential to performing radiosurgery of the SPG. CT provides the data necessary for calculation of beam attenuation by bone and brain, as well as for correction of distortions of the MRI. The MRI offers detailed soft-tissue anatomy, including visualization of the ganglion itself. Although useful in this study to confirm anatomic correlations of the cadaver dissection with CT and MRI, plain X-rays are not necessary to target the pterygopalatine ganglion with radiosurgery. CT and MRI images suffice.

Effects of radiosurgery

In this series, only the patient with classic cluster headache enjoyed long-term pain relief. The 2 patients with deafferentation pain experienced temporary relief for several months, followed by recurrence necessitating further medical or surgical therapy, such as motor cortex stimulation. The patient with migrainous headache with an important emotional component also failed bilateral SPG radiosurgery. These patients had symptoms suggesting sympathetic-mediated pain; however, other reasons for persistence of pain besides sympathetic/parasympathetic imbalance may have played a role in the maintenance of pain beyond radiosurgery. Apparently, the parasympathetic component of the facial pain syndrome, including the classic symptoms of cluster headache (e.g., periodicity, conjunctival injection, lacrimation, nasal congestion, rhinorrhea, perspiration, miosis, ptosis, eyelid edema) may be necessary for the effect of radiosurgery to be enduring.

The complications reported for radiofrequency thermoablation of the SPG include hyperesthesias of the palate, facial hematoma, hypersensitivity of the nasal mucosa, nose bleeding, and maxillary hyperpathia (22) were not observed after SRS in this study. The absence of major complications may be related to the excellent anatomic localization of the

SPG in the pterygopalatine fossa afforded by multimodality imaging. However, long-term follow-up may lead to identification of undesired effects of radiosurgery or delayed response to treatment for patients who did not experience relief.

CONCLUSION

Stereotactic radiosurgery of the sphenopalatine ganglion should play an increasing role for the treatment of facial pain syndromes. The excellence of a radiosurgical plan targeting to the sphenopalatine ganglion is optimal with the association of CT and MRI. Treatment of the SPG, whether by blockade, SRS, or other means, will continue to achieve variable results due to the difficult nature of chronic pain syndromes. The complex pathophysiologic and diagnostic aspects of chronic facial pain will continue to challenge physicians treating patients with these conditions. By allowing anatomic accuracy and mild side effects, SRS promises to be a useful tool for sphenopalatine ganglionectomy, when it is indicated.

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