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Transpalatal greater palatine canal injection: Radioanatomic analysis of where to bend the needle for pediatric sinus surgery

Kibwei A. McKinney, M.D., Michael E. Stadler, M.D., Yu-Tung Wong, M.D., Rupali N. Shah, M.D., Austin S. Rose, M.D., Carlton J. Zdanski, M.D., F.A.C.S., Charles S. Ebert Jr., M.D., M.P.H., Stephen A. Wheless, B.S., Brent A. Senior, M.D., Amelia F. Drake, M.D., and Adam M. Zanation, M.D.

Department of Otolaryngology–Head and Neck Surgery, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina

Abstract

Background—The greater palatine canal (GPC) local injection is used to limit posterior bleeding during sinus surgery in adults. Given the potential for causing iatrogenic damage to the intraorbital contents, this procedure is not commonly used in the pediatric population. No studies have described the anatomic development of the GPC during facial growth. By using age-stratified radioanatomic analysis, the dimensions of the GPC and the clinical implications are described for pediatric patients. An age-stratified radioanatomic study was performed.

Methods—High-resolution computed tomography measurements included the thickness of the mucosal plane overlying the GPC, the length of the GPC, and the distance between the base of the pterygopalatine fossa (PPF) and the orbital floor. Mean distance and standard deviation were calculated for each age cohort and compared using the one-way ANOVA test.

Results—The GPC length correlated directly with patient age. It varied from 9.14 ± 0.11 mm in the youngest age group (<2 years) to 19.36 ± 2.76 mm in adults (18–64 years). The height of the orbit relative to the hard palate approximated the adult dimensions described in the literature by 12–13 years (49.58 ± 1.72 mm).

Conclusion—These radioanatomic results suggest that the GPC injection described for adult patients may be safely administered to selected pediatric patients. For patients >12 years old, we recommend bending the needle 45° and inserting it 25 mm. For patients 6–12 years old, the needle should be inserted 20 mm to enter into the PPF. In patients <6 years old, the needle may safely be placed 12 mm into the GPC. Each of these descriptions is based on the minimal distance required to effectively access the PPF but with maximal safety in regard to the orbit. Further clinical correlation of these findings is necessary through future investigation.

Injection of the greater palatine canal (GPC) has been well-described in adults for the purposes of controlling posterior nasal hemorrhage, anesthetizing branches of the maxillary division of the trigeminal nerve traversing the pterygopalatine fossa (PPF), and relief of sphenopalatine neuralgia.^{1–4} Accepted indications include preoperative infiltration for endoscopic sinus surgery and septorhinoplasty, management of refractory epistaxis, regional blocks for dental procedures, and the treatment of sphenopalatine neuralgia.^{2–4} The canal provides direct access to the contents of the PPF, including the sphenopalatine ganglion,

Address correspondence and reprint requests to Adam M. Zanation, M.D., Department of Otolaryngology–Head and Neck Surgery, University of North Carolina Memorial Hospitals, 170 Manning Drive, Ground Floor Physician Office Building, CB#7070, Chapel Hill, NC 27599, adam_zanation@med.unc.edu.

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pterygopalatine ganglion, infraorbital nerve, internal maxillary artery, and the pterygoid venous plexus.^{3,4} Because of the direct communication of the PPF with the infraorbital fissure and the close relationship of these structures to the greater palatine foramen (GPF), this injection carries a significant risk of complications. These may include intravascular injection with associated cardiovascular side effects, blindness due to vasoconstriction of the ophthalmic artery, infraorbital nerve injury, PPF and/or infratemporal fossa abscess, and meningitis.^{1,2,5} In a case series of >200 patients over a 2-year period describing the use of this technique, Rankow documented the incidence of both transient and permanent blindness resulting from its use.^{6,7} These risks and an incomplete understanding of the anatomic changes that occur in this region during development have limited the use of this procedure in pediatric patients. Anatomic elucidation of a safe method for delivering the greater palatine injection in pediatric patients thus constitutes an addition to the armamentarium in the treatment of dental and sinonasal conditions in children.

Our group previously established that high-resolution computed tomography (HRCT) is an accurate and effective modality for measuring the structures of the anterior skull base in pediatric patients and correlating these clinically.⁸ Other radioanatomic studies have successfully used HRCT to estimate the length of the GPC in cadaveric specimens and adult patients.^{1,2,9,10} Cephalometric trends suggest that the most active phase of growth of the anterior skull base occurs during the first 5 years of life, followed by a plateau of growth from 5 to 15 years of age.^{8,11} Conversely, growth of the midface is relatively quiescent during early childhood, but rapidly increases after the age of 5 years.^{8,12} In the present study, we used HRCT to measure the thickness of the mucosal plane overlying the GPF, length of the GPC, distance between the base of the PPF and the orbital floor (OF), and the distance between the GPF and the sphenopalatine foramen (SPF) in a series of 50 pediatric patients. We stratified the patients according to age and compared them with a group of 10 adult patients. From this analysis, we describe a safe and clinically applicable method for performing the infiltration of the GPC in pediatric patients.

MATERIALS AND METHODS

Radioanatomic Methods

Institutional Review Board approval was given to review the maxillofacial CT scans of 50 pediatric and 10 adult patients. The pediatric cohort was comprised of individuals <18 years of age who had a noncontrast maxillofacial CT obtained over a 24-month period, identified through the IMPAX system by a neuroradiologist (B.H.; Agfa HealthCare, Mortselt, Belgium). These patients were collected consecutively, until 8–12 patients met each of the designated age strata. CT scans were performed using 0.75- to 3-mm axial section protocols with multiplanar reconstruction in the sagittal and coronal planes. Of these scans, the majority (80%) were 1-mm sections, 15% were sectioned in 2-mm slices, and 5% were 3-mm sections. Each of the scans were evaluated preliminarily by a pediatric otolaryngologist (C.Z.) or a skull base surgeon (A.Z.) to assess for motion artifact and image quality to ensure complete visibility of the GPC. Patients with imaging that did not meet this criterion were excluded. Three-millimeter section protocols were only included if the entirety of the GPC could be visualized on a single section.

Scans were stratified into one of six noncontiguous age groups: <24 months ($n = 8$), 3–4 years ($n = 8$), 6–7 years ($n = 9$), 9–10 years ($n = 8$), 12–13 years ($n = 8$), or 15–16 years ($n = 9$). For each of the subjects, the electronic medical record was reviewed to discern the presence of a medical history that would predispose to aberrant craniofacial or skull base anatomy. Patients were specifically excluded if they had evidence of preexisting conditions such as previous sinus or skull base surgery, congenital midface anomalies (craniosynostosis, hemi-facial microsomia, *etc.*), nasal polyposis, premature birth, and

history of skull base trauma. Of these, maxillofacial trauma was the most frequently encountered reason for exclusion. The resulting cohorts were each comprised of six to seven patients. Ten maxillofacial CT scans were performed on adult patients who met the same inclusion and exclusion guidelines. Measurements were performed on each of the scans by a pediatric otolaryngologist (C.Z.) and skull-base surgeon (A.Z.) using a PACS system (Agfa HealthCare). For measurements that differed between observers by <5%, the mean of the two distances was calculated as the value of this measurement. Inter-reader variability of >5% was discussed by the two independent observers and a final determination of the value of the measurement was made. Measurements were averaged according to age group and standard deviations were calculated.

Measurements

A summary of all the measurement definitions is provided in Table 1 and illustrated in Fig. 1, A and B. Bilateral measurements were performed using the technique described by Douglas *et al.*² The distance from the mucosa to the orbit (GPF-OF) was calculated as the sum of three independent measurements: the width of the mucosa overlying the GPF (mucosa), the distance traversed by the GPC (from the GPF to the PPF; GPC), and the distance from the base of the PPF to the floor of the orbit (PPF). In addition, the superoinferior distance from the GPF to the SPF was measured (GPF-SPF).

Statistical Analysis

Mean distance, standard deviation, and population variance were calculated for each of the age cohorts. These values were compared using a one-way ANOVA test and were considered to be statistically different for values of $p < 0.05$.

RESULTS

GPC Length and Distance to OF

Interobserver variability differed by <5% for all of the measurements. The distance from the GPF to the OF was calculated from the sum of the mucosal thickness overlying the GPF, the GPC length, and the height from the base of the PPF to the OF. Measurements were performed on reconstructed images in the sagittal plane. Each of the anatomic dimensions correlated directly with age in a linear fashion. The variation in mucosal thickness was from 4.38 ± 0.7 mm in the youngest age group to 9.21 ± 0.94 mm in the oldest age group. A similar distribution was noted in GPC length, from 9.14 ± 1.07 mm to 20.06 ± 1.31 mm. The range of PPF measurements varied from 12.60 ± 1.41 mm to 22.77 ± 1.86 mm. The computed distance from the GPF to the OF varied from 26.11 ± 0.24 mm among patients <24 months of age to 52.03 ± 0.21 mm in patients 15–16 years of age (Table 1). No statistically significant differences in these measurements were found between the right and left sides in subjects.

Table 1 shows the distribution of measurements within the various age cohorts. The mean values of GPC length, SPF length, and distance from GPF to OF changed significantly between contiguous age cohorts from <24 months to 12–13 years of age ($p < 0.05$). However, these dimensions showed no statistically significant changes between 12–13 and 15–16 years of age or between these two groups and the adult cohort ($p > 0.05$), signifying cessation of the active growth phase of these structures before these ages. The mean values of each measurement and corresponding p values for the statistical comparisons are displayed in Tables 1 and 2.

Distance to the SPF

The mean length of this distance varied from 15.34 ± 1.89 mm in the youngest pediatric group to 26.79 ± 1.73 mm in the oldest group. Among adults, this distance was found to be 25.90 ± 2.06 mm. A one-way ANOVA revealed no statistically significant difference in mean distance to the SPF beyond 12 years of age. Again, there were no statistical differences noted between the two sides. Mean values for the GPF to SPF distance and *p* values for the statistical comparisons between contiguous age groups are reported in Tables 1 and 2.

DISCUSSION

The GPF injection has been used for years, first being described for use in dental procedures, with anesthesia of the second division of the trigeminal nerve.^{11–13} Subsequently, this procedure was described and modified in the otolaryngology—head and neck surgery literature for use in endoscopic sinus surgery.^{1,4} In its original description, 1–1.5 mL of anesthetic was injected to a depth of 38–48 mm through the GPF.¹² These parameters were subsequently modified to decrease the risk of potential orbital complications associated with the procedure.¹⁴ Based on further experience and HRCT measurements, the most recent recommendation is for the needle to be bent to an angle of 45°, 25 mm from the needle tip.^{1,2,4} Small volumes of local anesthetic (1–2 mL) are then delivered through the GPC into the PPF.^{1,2,4} With endoscopic sinus surgery now commonly performed for a multitude of indications, experience with this injection has been shown to be very effective in minimizing hemorrhage and improving visualization during the surgical procedure.^{1,2}

Endoscopic sinus surgery has become a highly used option in the treatment algorithm for pediatric chronic sinusitis, often seen as the definitive surgical modality for treatment of the disease.^{15–17} Despite the wide acceptance of pediatric sinus surgery, there is a paucity of literature on the appropriate use of the GPF injection in this population. The importance of the safe use of this injection can not be overstated, because the associated complications can be especially problematic and devastating for these patients. The complexities of skull base and midfacial development, as they relate to age, demand for a dedicated study of the pediatric GPF and PPF. Ultimately, a well-defined method for the GPF injection will assist in performing this procedure with limited complication rates.

In this study, the mean length of the GPC and the GPF-SPF distance correlated directly with the age of the patient in a linear fashion up to the age of 12–13 years. Although the adult GPF-OF distance differed slightly from the result of a previous radioanatomic study (40 ± 3 mm), the methodology used in that report did not account for the thickness of the mucosa overlying the GPF, thus underestimating the true height of the OF.¹ After the age of 12–13 years, all of these measurements approximated the adult dimensions previously described in the literature and validated in our adult population.^{1,2}

These findings are supported by previous studies showing slowing of the active growth phase of the midface during early adolescence. In a cephalometric study of 542 pediatric cadavers, Waitzmann *et al.* used HRCT to show that 85% of the growth of the anterior cranial base occurs before 5 years of age.¹² The development of the cranio-orbitozygomatic skeleton slows thereafter and does not appreciably increase in size after 17 years of age. Conversely, the active growth phase of the upper midface was not shown to begin until after 5 years and continues until the middle of adolescence. Changes in these structures after midadolescence were attributed to fluctuations in the data rather than a discernible pattern of skeletal growth.¹² Our findings that show a leveling off of growth after the age of 12 are

consistent with these cephalometric data, which predict only minimal changes in the maxillofacial skeleton after the onset of puberty.

These radioanatomic results suggest that the GPC injection could be safely performed in pediatric patients. In performing this injection, the goal should be to maximize safety of the intraorbital contents by minimizing the depth of insertion required to access the PPF. In patients >12 years of age the injection may be performed in the manner presently described for adult patients, whereby the needle is bent to an angle of 45° at distance of 25 mm from the needle tip. This would effectively maintain a distance of 20 mm between the needle tip and the OF. In patients between 6 and 12 years of age the needle may be inserted up to 20 mm, also remaining 20 mm from the OF. In our youngest age groups (<6 years), the needle may be safely inserted to a depth of 12 mm, thereby keeping the needle tip 15 mm from the orbit. All of these measurements place the needle in the superior third of the GPC for infiltration of injectant while maximizing the distance from the orbital contents.

This study is limited by the use of radioanatomic measurements on HRCT to approximate true anatomic dimensions. However, with technological advancements of HRCT and improved resolution of digital viewing stations, this imaging modality is a very reasonable and accurate anatomic proxy that can be easily applied in the clinical setting. In addition, we did not detect any difference based on gender, but this study was not powered to further subdivide the study group. Given that the onset of puberty is the critical event that affects the slowing of skeletal growth and that age of onset differs significantly between males and females subjects, one would expect to find gender differences in the anatomic dimensions studied. This constitutes an area of future investigation.

Because of the purely radioanatomic nature of this study, caution should be exercised in interpreting these results for clinical use. Correlation of these findings through a larger prospective clinical design would be useful in assessing the safety, reproducibility, and efficacy of this technique in clinical practice. Additionally, it may be beneficial to evaluate the use of this procedure in patients with sinusitis and other sinonasal pathologies, given the impact of these phenomena on craniofacial growth and the stated goal of this injection in the treatment of these processes.

CONCLUSIONS

These radioanatomic results suggest that the GPF injection may be safely undertaken in pediatric patients >12 years of age without any increased risk of injury to intraorbital contents. Specifically, we recommend bending the needle to an angle of 45° with insertion to 25 mm in patients >12 years, thus remaining 20 mm from the OF. In patients 6–12 years old, the needle may be inserted up to 20 mm, thus maintaining a distance of the needle tip 20 mm, thus remaining 20 mm from the OF. Finally, for patients <6 years old, the needle tip may be inserted up to 12 mm, thereby keeping the needle tip 15 mm from the OF. All of these descriptions maximize safety to the intraorbital contents by minimizing the depth of insertion required to effectively deliver agents to the PPF. Further clinical correlation of these findings is required to support the efficacy and usefulness of this injection in a pediatric cohort.

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Figure 1. Noncontrast high-resolution computed tomography scans of (A) a pediatric patient <24 months old and (B) an adult patient 18–64 years of age. Parasagittal reconstructions are depicted here with measurements noting the mucosal thickness (mucosa), the length of the greater palatine canal (GPC), and the pterygopalatine fossa (PPF).

Table 1

Averages ($\pm$ standard deviation) of radioanatomic measurements of various anatomic dimensions stratified by age

Anatomic Dimension	<24 mo (mm)	3–4 yr (mm)	6–7 yr (mm)	9–10 yr (mm)	12–13 yr (mm)	15–16 yr (mm)	18–64 yr (mm)
Mucosa	4.37 $\pm$ 0.77	5.74 $\pm$ 0.65	5.82 $\pm$ 0.63	6.43 $\pm$ 0.81	7.93 $\pm$ 0.93	9.21 $\pm$ 0.94	9.39 $\pm$ 1.60
GPC	9.14 $\pm$ 0.11	11.85 $\pm$ 1.35	15.28 $\pm$ 1.99	16.59 $\pm$ 2.27	19.84 $\pm$ 1.09	20.06 $\pm$ 0.17	19.36 $\pm$ 2.76
PPF	12.60 $\pm$ 1.41	15.69 $\pm$ 0.65	18.20 $\pm$ 2.21	19.41 $\pm$ 1.90	21.81 $\pm$ 1.90	22.77 $\pm$ 1.85	21.07 $\pm$ 1.08
GPF-OF	26.11 $\pm$ 2.47	33.28 $\pm$ 1.51	39.30 $\pm$ 4.18	42.42 $\pm$ 4.13	49.58 $\pm$ 1.72	52.03 $\pm$ 2.06	49.82 $\pm$ 4.26
GPF-SPF	15.34 $\pm$ 1.89	19.79 $\pm$ 0.82	21.92 $\pm$ 2.24	22.02 $\pm$ 2.33	25.30 $\pm$ 2.63	26.79 $\pm$ 1.73	25.90 $\pm$ 2.06

GPC = greater palatine canal; PPF = pterygopalatine fossa; GPF-OF = distance between greater palatine foramen to orbital floor; GPF-SPF = distance from greater palatine foramen to sphenopalatine foramen.

Table 2

Mean differences between age groups as reported by ANOVA testing (with associated *p*-values)

Anatomic Dimension	Mean Difference between Contiguous Age Groups (mm)									
	<24 mo to 3-4yr	3-4 yr to 6-7yr	6-7 yr to 9-10 yr	9-10 yr to 12-13 yr	12-13 yr to 15-16 yr	15-16 yr to 18-64 yr				
Mucosa	1.36 (<0.05)	0.08 (>0.05)	0.60 (>0.05)	1.50 (<0.01)	1.29 (<0.05)	0.18 (>0.05)				
GPC	2.71 (<0.05)	3.43 (<0.01)	1.31 (>0.05)	3.25 (<0.01)	0.22 (>0.05)	0.70 (>0.05)				
PPF	3.09 (<0.05)	2.51 (>0.05)	1.21 (>0.05)	2.40 (>0.05)	0.95 (>0.05)	1.70 (>0.05)				
GPF-OF	7.16 (<0.01)	6.03 (<0.01)	3.13 (>0.05)	7.15 (<0.01)	2.46 (>0.05)	2.21 (>0.05)				
GPF-SPF	4.45 (<0.01)	2.14 (>0.05)	0.10 (>0.05)	3.28 (<0.05)	1.49 (>0.05)	0.89 (>0.05)				

GPC = greater palatine canal; PPF = pterygopalatine fossa; GPF-OF = distance between greater palatine foramen to orbital floor; GPF-SPF = distance from greater palatine foramen to sphenopalatine foramen.