The parasellar region of human infants: cavernous sinus topography and surgical approaches

WOLFGANG J. WENINGER, M.D., AND GERD B. MÜLLER, M.D., PH.D.

Department of Anatomy, University of Vienna, Vienna, Austria

Object. In this study the authors analyze the peculiarities of the parasellar anatomy and the topography of surgical approaches to the parasellar region (PSR) in human infants.

Methods. Forty-nine specimens of the PSR obtained at autopsy were studied using microdissection and histological analysis. Important distances between anatomical landmarks were measured with the aid of a dissecting microscope. One serially sectioned specimen was three-dimensionally reconstructed and analyzed on the computer screen by using the authors’ new episcopic reconstruction technique.

Conclusions. The anatomy of the infant PSR differs distinctly from that of the adult. The parasellar portion of the internal carotid artery (ICA) does not form a siphon, but takes a straight course, and the venous pathways as well as the cranial and sympathetic nerves have different topographical relationships. Analyses of surgical approaches demonstrate that, in young children, the anterolateral approach can be used to reach the pterygopalatine compartment, the superior ophthalmic vein, and those pathological processes that extend from the orbit into the PSR. The approach via Parkinson’s triangle can be used in 45% of cases to access the pathological processes that occur in the voluminous space above and behind the posterior flexure of the parasellar ICA. Taking this route, sympathetic nerve fibers passing through the PSR are not at risk, but some arterial branches that run within the lateral wall of the sinus can complicate this approach.

This study presents a guideline that can assist radiologists and neurosurgeons in the planning and performance of interventions within the PSR of neonates and young children.

KEY WORDS • parasellar region • cavernous sinus • three-dimensional reconstruction • Parkinson’s triangle • surgical approach • neonate • children

A number of disease processes occur in the cavernous sinus region of neonates and young children.2,4,6,11,15,19,46 These often require neurosurgical interventions,33–36 treatment using invasive radiological techniques,1,5,29,40 or radiotherapy.7,9 All manipulations within this narrow space require an exact knowledge of the particular parasellar topography in infants.33 However, all detailed descriptions of cavernous sinus anatomy,3,27,31,42 measurements of important distances,14,20–22 and analyses of surgical approaches8,10,18,32,37,38 have been based on adult specimens. Fetal structures have been studied by Padget,28 Knosp and associates,16 and Solassol, et al.;39 however, information about structures in young children is scarce. The space lateral to the sella turcica is termed the “parasellar region” (PSR) and consists of three separate compartments.55 Exact anatomical descriptions of the peculiar infant topography, pathways for surgical approaches, and measurements of important distances thus far have not been available. The goal of this study is to improve the anatomical knowledge of this confined space and to serve as a guideline for radiologists and neurosurgeons.

Materials and Methods

Forty-nine PSRs of human infants, aged between 0 and 9 months (mean 4.3 months) were removed from skull bases at autopsy and were fixed in 3.7% neutral buffered formaldehyde. Twenty specimens obtained from the left side and 24 from the right side were microdissected, measured, and photographed with the aid of a dissecting microscope.

One specimen (obtained in an infant who died at 3 weeks of age) was reconstructed in a three-dimensional manner on the computer so that our findings could be verified and better visualized. The PSR was dehydrated in saturated ethanol/lead acetate solutions, embedded in Paraplast, and sectioned on a specially adapted rotation microtome. Subsequently, sections were dyed with standard hematoxylin and eosin, Goldner’s, and Mallory’s stains.

One specimen (obtained in an infant who died at 3 weeks of age) was reconstructed in a three-dimensional manner on the computer so that our findings could be verified and better visualized. The PSR was dehydrated in saturated ethanol/lead acetate solutions, embedded in Paraplast, and sectioned on a specially adapted rotation microtome. Subsequently, sections were dyed with standard hematoxylin and eosin, Goldner’s, and Mallory’s stains.

A J Neurosurg. / Volume 90 / March, 1999
reconstructed in a three-dimensional fashion by using reconstruction software. For details of the technique, see Weninger, et al.14

Sources of Supplies and Equipment

The Wild–Heerbrugg M-8 dissecting microscope, the Leitz rotation microtome (model 1516), and the Reichert-Jung rotation microtome (model 2030) used for the three-dimensional reconstruction were purchased from Leica Microsystems (Wetzlar, Germany). The Cal-Ex was obtained from Fisher Scientific (Orangeburg, NY) and the Paraplast from Sigma Chemical Co. (St. Louis, MO). The Microwatcher VS 90 video microscope was provided by Mitsubishi Corp. (Tokyo, Japan). We used a Macintosh PowerPC 8500/180 computer obtained from Apple Computer, Inc. ( Cupertino, CA) and Silicon Graphics Workstation (Iris Indigo XL24) obtained from Silicon Graphics, Inc. (Mountain View, CA). Image software, version 1.6, was provided by the National Institutes of Health (Bethesda, MD) and the reconstruction software, Image Volumes, version 2.2, by Minnesota Datametrics (St. Paul, MN).

Results

Topography of the PSR in Infants

As in adults, the internal carotid artery (ICA) enters the PSR in infants through the carotid canal and, traditionally, is said to form the carotid siphon. In 92% of our cases, the angle of the posterior knee of the carotid siphon was greater than 70°; therefore, the parasellar portion of the ICA rarely formed a characteristic siphon in the infant. In 25% of our cases the course of the ICA was almost completely straight with an angle at the posterior knee measuring more than 130°. We thus use the term “parasellar portion,” rather than “carotid siphon,” throughout the text. The straight course of the ICA causes a voluminous connective tissue space in the upper posterior portion of the PSR (Fig. 1). This space is filled by branches of the artery, the venous plexus, and sometimes by adipose tissue islands (in 33% of cases). In none of our specimens did any segment of the ICA lie directly adjacent to the lateral wall of the cavernous sinus. The ICA leaves the PSR, perforating the diaphragma sellae medially from the tip of the anterior clinoid process. On average, the center of its lumen is located 5.56 mm lateral to the median sagittal plane (Table 1).

Two large vessels and several small branches originate from the parasellar portion of the ICA (Fig. 1). The small branches arise from the medial surface of the artery and supply the pituitary gland. The meningohypophyseal trunk arises from the vertex of the posterior knee. It rami-}

distances were purchased from Leica Microsystems (Wetzlar, Germany). The Microwatcher VS 90 video microscope was provided by Mitsubishi Corp. (Tokyo, Japan). We used a Macintosh PowerPC 8500/180 computer obtained from Apple Computer, Inc. (Cupertino, CA) and Silicon Graphics, Inc. (Mountain View, CA). Image software, version 1.6, was provided by the National Institutes of Health (Bethesda, MD) and the reconstruction software, Image Volumes, version 2.2, by Minnesota Datametrics (St. Paul, MN).

Results

Topography of the PSR in Infants

As in adults, the internal carotid artery (ICA) enters the PSR in infants through the carotid canal and, traditionally, is said to form the carotid siphon. In 92% of our cases, the angle of the posterior knee of the carotid siphon was greater than 70°; therefore, the parasellar portion of the ICA rarely formed a characteristic siphon in the infant. In 25% of our cases the course of the ICA was almost completely straight with an angle at the posterior knee measuring more than 130°. We thus use the term “parasellar portion,” rather than “carotid siphon,” throughout the text. The straight course of the ICA causes a voluminous connective tissue space in the upper posterior portion of the PSR (Fig. 1). This space is filled by branches of the artery, the venous plexus, and sometimes by adipose tissue islands (in 33% of cases). In none of our specimens did any segment of the ICA lie directly adjacent to the lateral wall of the cavernous sinus. The ICA leaves the PSR, perforating the diaphragma sellae medially from the tip of the anterior clinoid process. On average, the center of its lumen is located 5.56 mm lateral to the median sagittal plane (Table 1).

Two large vessels and several small branches originate from the parasellar portion of the ICA (Fig. 1). The small branches arise from the medial surface of the artery and supply the pituitary gland. The meningohypophyseal trunk arises from the vertex of the posterior knee. It rami-}

Distances Within the PSR in Infants

The measurements taken from all microdissected specimens provided a number of quantitative data important for neurosurgical approaches and radiological diagnosis. All distances are given as mean values. The distance between the bottom of the medial cranial fossa and the petroclinoidal fold, at the level of the stalk of the pituitary gland, is 13.54 mm. The petroclinoidal fold is situated 9.34 mm lateral to the median sagittal plane. The distance between the tip of the anterior clinoid process and the tip of the posterior clinoid process measures 8.09 mm.

The oculomotor, trochlear, trigeminal, and abducent nerves pass through the PSR (Fig. 1). Distal to their entrance through “dural pores,” they are ensheathed by invaginations of the meningeal dural layer for a few millimeters. The distances between the dural pores and various osseous landmarks are given in Table 1.

Surgical Approaches

Two lateral approaches to structures inside the PSR are recommended for infants. The lower anterior portion of the PSR can be reached by the anterolateral approach, entering between the ophthalmic and maxillary portion of the trigeminal nerve. The upper posterior portion of the PSR is best reached through Parkinson’s triangle, the space between the upper rim of the trigeminal nerve and the lower rim of the trochlear nerve (Fig. 4).

Anterolateral Approach. In 80% of the cases, the pterygopalatine compartment was located immediately underneath the dura mater and had to be opened if the anterolateral approach was used. The pterygopalatine compartment connects to extracranial tissue spaces. It contains the parasellar adipose body (Figs. 3 and 4) and a ganglion that is reached by sympathetic nerve fibers from the internal carotid plexus via the trochlear nerve. The superior ophthalmic vein runs between the pterygopalat-
Fig. 1. Three-dimensional reconstructions of a serially sectioned PSR obtained at autopsy from a human infant aged 3 weeks. Oblique lateral views (frontal on left) showing the topographical relationships between the sphenoid bone (tan), cranial nerves (green), veins (blue), arteries (reddish brown), and adipose tissue bodies (yellow). Upper Left: Topography of the lateral wall. The parasellar adipose body can be reached through the anterolateral approach, whereas Parkinson’s triangle can be used to reach the meningohipophyseal trunk. Note the course of the superior ophthalmic vein. Upper Right: Cranial nerves of the lateral wall. The ophthalmic and oculomotor nerves ramify within the orbital compartment, which is represented by the orbital adipose body (yellow). Note the motor portion of the trigeminal nerve (arrow). Center Left: Course of the abducent nerve. The anteromedial branch of the inferolateral trunk accompanies the abducent nerve. Although sympathetic nerve fibers were not reconstructed, their connection to the abducent nerve is visible in front of the C1 segment of the ICA (arrow). Center Right: Cranial nerves and arteries. Note the inferolateral trunk, which descends between the ophthalmic portion of the trigeminal nerve and the abducent nerve (arrow). Lower Left: Blood vessels of the PSR. The inferior ophthalmic vein (arrow) drains into the superior ophthalmic vein below the anterior knee of the carotid siphon. The arterial trunks of the carotid siphon ramify in the usual manner. Lower Right: The PSR after removal of the trigeminal nerve. Bars = 1 mm.
Parasellar region in the infant

### Table 1

<table>
<thead>
<tr>
<th>Landmark Distance (in mm)</th>
<th>Rt Side Mean (range)</th>
<th>Lt Side Mean (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>height of PSR</td>
<td>13.83 (11.1–16.45)</td>
<td>13.24 (10.45–16.3)</td>
</tr>
<tr>
<td>MSP–petroclinoidal fold</td>
<td>8.95 (6–13.75)</td>
<td>9.73 (5.6–12.4)</td>
</tr>
<tr>
<td>ACP–PCP</td>
<td>7.93 (5.65–10)</td>
<td>8.25 (6.15–10)</td>
</tr>
<tr>
<td>PCP–DP of CN III</td>
<td>3.95 (2.6–6.55)†</td>
<td>4.02 (2.25–5.8)†</td>
</tr>
<tr>
<td>MSP–DP of CN V</td>
<td>10.72 (7.75–13.1)</td>
<td>10.79 (6.65–14.6)</td>
</tr>
<tr>
<td>MSP–DP of CN VI</td>
<td>6.41 (3.9–10.05)</td>
<td>10.58 (6.65–14.6)</td>
</tr>
<tr>
<td>dorsum sellae–DP of CN VI</td>
<td>11.54 (8.8–15.45)</td>
<td>8.62 (6–10.8)</td>
</tr>
<tr>
<td>MSP–ICA</td>
<td>5.64 (4.25–6.4)</td>
<td>5.48 (4.25–6.95)</td>
</tr>
</tbody>
</table>

* Note the differences between the right and left sides. Abbreviations: ACP = anterior clinoid process; CN = cranial nerve; DP = dural pore; MSP = median sagittal plane; PCP = posterior clinoid process.
† In front of the PCP.

Discussion

Various tumors that occur in the PSR of children during their 1st year of life require surgical treatment. In addition to these primary intracranial tumors, a number of pathological processes of the orbital apex can extend into the PSR. They are treated by both ophthalmologists and neurosurgeons. As Pikus, et al., have emphasized, an exact knowledge of the parasellar anatomy is critical for surgical interventions within this space. Extremely careful preparation is necessary because of the limited blood volume and cardiovascular reserve of young children. In this study we present a basis for safe approaches to pathological processes occurring within the PSR of infants.

**Fig. 2.** Photograph showing the course of the superior branch of the inferolateral trunk (arrowhead orientation: frontal on right). Two small branches (arrows) perforate the trochlear nerve.

**Topography of the PSR in Infants**

In infants, the space lateral to the sella turcica is preferably called the “parasellar region” and consists of three separate compartments. In adults, the parasellar portion of the ICA forms the carotid siphon. The angle of its posterior knee measures 15 to 120° and mostly fills the upper posterior portion of the PSR. In contrast, the course of the parasellar portion of the infant ICA is much straighter and, therefore, the upper lateral portion of the PSR is very spacious. The blood vessel is never fully adjacent to the lateral wall of the PSR, as it is in 14% of adults. The parasellar trunks of the ICA originate and ramify in the same manner as described for fetuses and adults. We recognized McConnell’s arteries, but their origins were not further analyzed.

In all specimens the occipital portion of the PSR harbored a venous plexus, whereas the frontal portion merely contained some small veins and the large superior ophthalmic vein running between the orbital and pterygopalatine compartments. These findings support earlier notions that reject the presence of a septate cavernous sinus in adults and instead postulate a parasellar venous plexus. Cannulation of the superior ophthalmic vein sometimes is used for radiological diagnosis and transvenous treatment of arteriovenous malformations. The relationship with the pterygopalatine compartment opens the possibility of cannulating the superior ophthalmic vein through the infratemporal fossa via the pterygopalatine compartment or directly through the anterolateral approach.

The positions of the dural pore entrances of the cranial nerves in relation to osseous landmarks differ between adults and children. For example, in adults the dural pore of the oculomotor nerve is mostly situated at the level of the posterior clinoid process or even far behind this process. In contrast, the infant dural pore is always situated in front of the posterior clinoid process (on average 3.99 mm). This corresponds to approximately half the distance between the anterior and posterior clinoid processes.

All these anatomical differences between adults and infants demonstrate that the infant’s PSR does not represent a small version of the adult cavernous sinus. The
osseous structures bordering this space undergo continuous transformations throughout childhood, as do the tissues and structures of the PSR. Therefore, existing topographic analyses of the adult cavernous sinus region do not provide sufficient orientation for neurosurgery and neuroradiology.

**Surgical Approaches**

In infants, the anterolateral approach through the triangle between the ophthalmic and the maxillary portions of the trigeminal nerve opens the pterygopalatine compartment and uncovers the superior ophthalmic vein. Through this approach, the frontal portion of the PSR, which contains the parasellar adipose body, the vein, and the anterolateral branch of the inferolateral trunk of the ICA can be reached. Moreover, the location of the superior ophthalmic vein, immediately beneath the dura mater in the anterolateral approach, may lead to further ideas for using this location for intravascular approaches to the parasellar venous plexus.

Until now, measurements and analyses of surgical approaches made through Parkinson’s triangle were only available for adults. We propose that a height of more than 3 mm for Parkinson’s triangle is the limiting factor for safe approaches and we found distances exceeding this

---

**Fig. 3.** Photograph and photomicrograph showing the topography of the anterior portion of the PSR. The superior ophthalmic vein (V) is located between the pterygopalatine compartment, which contains the parasellar adipose body (P), and the orbital compartment (O), more frontally located, which contains the orbital adipose body (asterisk). **Left:** Photograph of gross dissection (orientation: frontal on left). Note the relationship between the abducent and ophthalmic nerves. **Right:** Photomicrograph showing a frontal section. The section plane lies behind the occipital tip of the orbital adipose body. Arrows mark the lateral wall of the PSR. Small veins are scattered between the cranial nerves (arrowheads). Note the ganglion within the parasellar adipose body. Goldner’s stain, original magnification × 20.

**Fig. 4.** Photograph showing lateral approaches (orientation: frontal on left). The pterygopalatine compartment, containing the parasellar adipose body (P), and the ophthalmic vein are prepared using the anterolateral approach. The meningoophyseal trunk (arrow) and its branches are prepared using Parkinson’s approach. Note the superior branch of the inferolateral trunk below the trochlear nerve.

**Fig. 5.** Schematic drawing showing Parkinson’s triangle (orientation: frontal on left). The average height (vertical arrow), average length (horizontal arrow), and ranges of these values (noted in parentheses) are measured in millimeters. The dotted lines mark the clival side and the side along the lower rim of the trochlear nerve (IV). ACP = anterior clinoid process; III = oculomotor nerve; PCP = posterior clinoid process; V = trigeminal nerve.
limit in 45% of our cases. In 5% of our cases, in which the height was less than 3 mm, the PSR could be approached through the space between the oculomotor and trochlear nerves. Thus, in 50% of these cases, the upper posterior portion of the PSR could be reached without damaging any cranial nerve. In infants, the parasellar sympathetic pathways to the orbit, brain, and pineal gland form a common sympathetic trunk below the sagittal portion of the parasellar ICA.44 Thus, they are not at risk when Parkinson’s approach is used.

Conclusions
Anatomical analyses and measurements of important distances were performed in the infant PSR and were compared with those found in adults. It was found that important differences exist in the composition and topography of blood vessels and nerves. For example, in the infant, the parasellar portion of the ICA is surrounded by a venous plexus and does not form a characteristic siphon; the superior ophthalmic vein is located between the orbital and parasellar adipose bodies before it turns medially to continue between the ICA and the sphenoid bone; the entrance to the dural pore of the oculomotor nerve is situated midway between the anterior and posterior clinoid processes. In addition to these anatomical descriptions, topographical analyses and measurements applicable to the anterolateral surgical approach and to Parkinson’s triangle were performed. We describe in detail the structures that can be approached safely through these pathways, as well as situations that may complicate surgical interventions. Thus our study can serve as a guideline for radiologists and neurosurgeons in the treatment of parasellar diseases in neonates and young children.

Acknowledgments
We thank Christian Reiter and Silvi Rabl for valuable comments, and Bernhard Strauss and Johannes Streicher for technical support.

References
W. J. Weninger and G. B. Müller


Manuscript received June 19, 1998.
Accepted in final form October 9, 1998.
Address reprint requests to: Wolfgang J. Weninger, M.D., Department of Anatomy, Währingerstrasse 13, A-1090 Vienna, Austria, European Union. email: Wolfgang.Weninger@univie.ac.at.