Selective extradural anterior clinoidectomy for supra- and parasellar processes

Technical note

YASUHIRO YONEKAWA, M.D., NOBUYOSHI OGATA, M.D., HANS-GEORG IMHOF, M.D., MAGNUS OLIVECRONA, M.D., KEVIN STROMMER, M.D., TAE EON KWAK, M.D., PETER ROTH, AND PETER GROSICHTH, M.D.

Department of Neurosurgery, University Hospital of Zürich, and Institute of Anatomy, University of Zürich, Zürich, Switzerland

Removal of the anterior clinoid process (ACP) facilitates radical removal of tumors or radical neck clipping of aneurysms in the supra- and parasellar regions by providing a wide operative exposure of the internal carotid artery (ICA) and the optic nerve and by reducing the need for brain retraction.

Over a period of 3 years, anterior clinoidectomy was performed in 40 patients, 30 of whom harbored aneurysms (18 of the ICA and 13 of the basilar artery [one patient had two aneurysms]) and 10 of whom had tumors (four large pituitary tumors, four craniopharyngiomas, and two sphenoid ridge meningiomas). The ACP was removed extradurally in 31 cases and intradurally in nine cases.

Extradural clinoidectomy was performed in all cases of pituitary adenoma and craniopharyngioma and in most cases of basilar artery aneurysm. Intradural clinoidectomy was performed in two cases of ICA–ophthalmic artery aneurysm, two cases of ICA–posterior communicating artery aneurysm, two cases of ICA cavernous aneurysm, two cases of sphenoid ridge meningioma. The outcome was satisfactory in all patients, except for one patient who underwent clipping of a basilar tip aneurysm and suffered a thalamic and midbrain infarction. Three patients who underwent extradural clinoidectomy suffered a postoperative diminution of visual acuity or a visual field defect on the side of the clinoidectomy. These deficits may have been caused either by drilling of the ACP or by other operative manipulation of the optic nerve. Cerebrospinal fluid rhinorrhea, which required reoperation, occurred in one patient.

The authors’ experience suggests that the extradural technique of ACP removal is easier and less time consuming than the intradural one and provides better operative exposure. It can be used routinely in treating lesions in the supra- and parasellar regions.

Key Words • anterior clinoid process • aneurysm • brain tumor • operative technique

The need for removal of the anterior clinoid process (ACP) has been emphasized in previous descriptions of the surgical treatment of internal carotid artery (ICA)–ophthalmic artery (OA) and giant ICA aneurysms.5,6,8,12,13,19,20,24 It provides exposure of the ICA and optic nerve with less need for brain retraction.

The intradural technique of ACP removal has been described in detail.16,22 The extradural technique has been described as a component of a more extensive approach2,3 however, the indications for its use and its optimal extent remain to be clarified. With this in mind, we now present our experience in 40 cases of ACP removal, most of which involved the extradural approach.

Case Selection

The ACP was removed in 40 patients who underwent surgery at the Department of Neurosurgery, University Hospital of Zürich, between September 1993 and June 1996. The clinical data are listed in Table 1. There were 31 females and nine males in this group, and the mean age was 48 years (range 15–70 years).

The indications for surgery included 31 aneurysms in 30 patients (18 of the ICA and 13 of the basilar artery [one patient had two aneurysms]) and 10 of whom had tumors (four large pituitary tumors, four craniopharyngiomas, and two sphenoid ridge meningiomas). The ACP was removed extradurally in 31 cases and intradurally in nine cases.

Operative Technique

Extradural clinoidectomy was accomplished as follows. The position of the patient and fixation of the head are the same as those used in the standard pterional approach.23
After craniotomy and flattening of the sphenoid ridge with the usual drilling procedure, the dura is separated from the ACP up to the orbital roof over the optic sheath medially. With the aid of an operating microscope the ACP is then drilled away extradurally using a diamond burr. The ACP removal extends to the medial border of the optic nerve, to the lateral border of the dural entry into the superior orbital fissure, and approximately 1 cm anterior to the falciform fold of the optic nerve (Fig. 2). Drilling is begun at the portion of the sphenoid bone that overlies the lateral margin of the dural insertion into the superior orbital fissure. The drill is pointed medially and makes a right angle to the course of the optic canal. Next, the optic canal is unroofed from its medial margin laterally. Great care should be taken not to injure the underlying optic sheath or to carry the unroofing beyond the medial border of the optic canal and, thereby, open the ethmoid sinus. The lateral border of the roof of the optic canal, including the optic strut, must be completely transected at this stage to free the ACP for removal. A plane of dissection between the dura and the ACP is created using a microdissector, and the ACP is finally removed en bloc using a small rongeur. Bradycardia may occur at this point, probably because of trigeminal irritation by the dural traction. The anesthesiologist should be forewarned of this possibility. Profuse venous bleeding may also occur from tears in the epidural vein or the cavernous sinus. Application of oxycellulose with cotton sponge compression and slight elevation of the patient’s head should be adequate to bring the bleeding under control. A small piece of the optic strut usually remains laterocaudal to the optic nerve and may be drilled away in an anterocaudal direction.

**TABLE 1**

<table>
<thead>
<tr>
<th>Case</th>
<th>Age (yrs), Sex</th>
<th>Diagnosis</th>
<th>SAH Symptoms</th>
<th>Drilling Complications</th>
<th>GOS Score at 3 Mos</th>
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<tbody>
<tr>
<td>1</td>
<td>44, M</td>
<td>ICA cavernous aneurysm</td>
<td>incidental</td>
<td>intra</td>
<td>no</td>
</tr>
<tr>
<td>2</td>
<td>60, M</td>
<td>BA aneurysm</td>
<td>Grade I on Day 10</td>
<td>intra</td>
<td>no</td>
</tr>
<tr>
<td>3</td>
<td>44, F</td>
<td>giant ICA–OA aneurysm</td>
<td>Grade II on Day 3</td>
<td>intra</td>
<td>no</td>
</tr>
<tr>
<td>4</td>
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<td>unruptured (multiple)</td>
<td>extra</td>
<td>no</td>
</tr>
<tr>
<td>5</td>
<td>48, F</td>
<td>dorsal ICA aneurysm</td>
<td>Grade II on Day 3</td>
<td>extra</td>
<td>no</td>
</tr>
<tr>
<td>6</td>
<td>61, F</td>
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<td>extra</td>
<td>no</td>
</tr>
<tr>
<td>7</td>
<td>48, F</td>
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<td>extra</td>
<td>trans oculomotor paresis</td>
</tr>
<tr>
<td>8</td>
<td>46, F</td>
<td>BA aneurysm</td>
<td>Grade IV on Day 1</td>
<td>extra</td>
<td>comma, oculomotor paresis, thalamic &amp; brainstem infarct</td>
</tr>
<tr>
<td>9</td>
<td>41, F</td>
<td>giant ICA aneurysm between PCoA &amp; AChA</td>
<td>Grade III on Day 13</td>
<td>extra</td>
<td>no</td>
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<tr>
<td>10</td>
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<td>11</td>
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</tr>
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<td>no</td>
</tr>
<tr>
<td>13</td>
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<td>extra</td>
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<td>14</td>
<td>48, M</td>
<td>BA aneurysm</td>
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<td>trans lt hemiparesis w/ infarct in the thalamus (transsection of PCoA)</td>
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<td>15</td>
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<td>extra</td>
<td>meningitis w/ vent drainage</td>
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<td>16</td>
<td>36, F</td>
<td>BA aneurysm &amp; ICA–OA aneurysm</td>
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<td>extra</td>
<td>rt quadrantanopsia</td>
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<td>17</td>
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<td>extra</td>
<td>opening of sphenoid sinus</td>
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<td>18</td>
<td>51, F</td>
<td>sphenoid ridge meningioma</td>
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<td>extra</td>
<td>opening of ethmoid sinus, rhinoliquorrhea</td>
</tr>
<tr>
<td>19</td>
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<td>extra</td>
<td>trans oculomotor paresis</td>
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<tr>
<td>20</td>
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<td>no</td>
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<tr>
<td>21</td>
<td>15, M</td>
<td>hypophyseal tumor</td>
<td>NA</td>
<td>extra</td>
<td>no</td>
</tr>
<tr>
<td>22</td>
<td>49, F</td>
<td>ICA–OA aneurysm</td>
<td>incidental</td>
<td>intra</td>
<td>opening of sphenoid sinus</td>
</tr>
<tr>
<td>23</td>
<td>68, F</td>
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<td>Grade III on Day 1</td>
<td>intra</td>
<td>no</td>
</tr>
<tr>
<td>24</td>
<td>51, M</td>
<td>hypophyseal tumor</td>
<td>NA</td>
<td>extra</td>
<td>rt visual disturbance</td>
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<tr>
<td>25</td>
<td>54, M</td>
<td>distal SCA aneurysm</td>
<td>Grade III on Day 6</td>
<td>extra</td>
<td>no (hemiparesis from spasm)</td>
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<tr>
<td>26</td>
<td>30, M</td>
<td>hypophyseal tumor</td>
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<td>extra</td>
<td>no</td>
</tr>
<tr>
<td>27</td>
<td>57, F</td>
<td>ICA–OA aneurysm</td>
<td>Grade II on Day 0</td>
<td>extra</td>
<td>no (hemiparesis from spasm)</td>
</tr>
<tr>
<td>28</td>
<td>67, F</td>
<td>hypophyseal tumor</td>
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<td>extra</td>
<td>no</td>
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<tr>
<td>29</td>
<td>52, F</td>
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<td>unruptured (multiple)</td>
<td>extra</td>
<td>no</td>
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<tr>
<td>30</td>
<td>59, F</td>
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<td>intra</td>
<td>no</td>
</tr>
<tr>
<td>31</td>
<td>43, F</td>
<td>dorsal ICA aneurysm</td>
<td>Grade IV on Day 1</td>
<td>extra</td>
<td>no (hemiparesis from spasm)</td>
</tr>
<tr>
<td>32</td>
<td>65, F</td>
<td>ICA cavernous aneurysm</td>
<td>Grade II on Day 18</td>
<td>extra</td>
<td>PCA territory infarct</td>
</tr>
<tr>
<td>33</td>
<td>31, F</td>
<td>ICA–OA aneurysm</td>
<td>unruptured (multiple)</td>
<td>extra</td>
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<tr>
<td>34</td>
<td>70, F</td>
<td>BA–SCA aneurysm</td>
<td>Grade II on Day 1</td>
<td>extra</td>
<td>no</td>
</tr>
<tr>
<td>35</td>
<td>27, F</td>
<td>craniopharyngioma recurrence</td>
<td>visual disturbance</td>
<td>extra</td>
<td>no</td>
</tr>
<tr>
<td>36</td>
<td>61, F</td>
<td>large ICA–OA aneurysm</td>
<td>visual disturbance</td>
<td>extra</td>
<td>opening of sphenoid sinus</td>
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<tr>
<td>37</td>
<td>50, F</td>
<td>BA aneurysm</td>
<td>Grade I on Day 20</td>
<td>extra</td>
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<td>38</td>
<td>65, F</td>
<td>giant ICA–OA aneurysm</td>
<td>visual disturbance</td>
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<td>39</td>
<td>58, F</td>
<td>BA aneurysm</td>
<td>Grade I on Day 10</td>
<td>extra</td>
<td>no</td>
</tr>
<tr>
<td>40</td>
<td>47, F</td>
<td>BA aneurysm</td>
<td>Grade I on Day 20</td>
<td>extra</td>
<td>rt visual disturbance</td>
</tr>
</tbody>
</table>

* AChA = anterior choroidal artery; extra = extradural; GOS = Glasgow Outcome Scale; GR = good recovery; intra = intradural; MD = moderate disability; NA = not applicable; PCA = posterior cerebral artery; SAH = subarachnoid hemorrhage; trans = transient; unruptured (multiple) = unruptured aneurysm of multiple aneurysms, one bleeding; VS = vegetative state.
direction if required. If an en bloc removal of the ACP is not possible, the remaining bone fragments should be removed one at a time or drilled. However it is accomplished, total removal of the ACP is very important for the remainder of the procedure (Fig. 2 lower).

Once the ACP is removed, the dura is incised in a direction that runs parallel to the ACP. The optic sheath and the first dural ring of the ICA are opened for further mobilization of the optic nerve and the ICA. Sufficient mobilization of the optic nerve medially and cranially will permit the radical removal of a craniopharyngioma attached to the hypothalamus. It will also provide better visualization of the OA, so that even a large ICA–OA aneurysm can be clipped ideally, without need of a special fenestrated clip. Temporary clipping of the carotid artery at the C, portion is thus possible (Fig. 3).

Sufficient mobilization of the carotid artery medially and laterally will permit easier dissection of the BA–posterior cerebral artery–SCA complex. An appropriate combination of ACP and posterior clinoid process removal, sectioning of the PCoA, opening of the cavernous sinus at the anteromedial triangle, and lateral replacement of the dural complex over the removed ACP will provide sufficient room to occlude even a large aneurysm in this region (Fig. 4). The enlargement of the operative field by removal of the ACP using the aforementioned procedure is shown schematically in Fig. 5.

Selection of an Extradural or Intradural Approach

Clinoidectomy was performed extradurally, as just described, in all but nine of our 40 cases. In two cases of ICA–PCoA aneurysm, we did not expect that the ACP would have to be removed until we opened the dura. After dissecting the aneurysm, we found that there was no room to apply an aneurysm clip (Case 6) or a temporary clip (Case 23). Retrospectively, had we known the relationship between the aneurysms and the ACP in these cases, we would have removed the ACP extradurally.

In the two cases of sphenoid ridge meningioma, we first attempted extradural clinoidectomy, but were hampered by reactive hyperostosis and tumor infiltration of bone and by adherence of the dura to the ACP. We therefore decided to perform an intradural clinoidectomy after partial removal of the tumor. In four cases of ICA–OA aneurysms, we chose to perform an intradural clinoidectomy because the aneurysm was in direct contact with the ACP. In the remaining 31 cases, including all cases of pituitary adenoma and craniopharyngioma and most BA aneurysms, we used the extradural approach.

FIG. 1. Drawing showing that the position of the patient, fixation of the head, skin incision, and extent of craniotomy are the same as those used in the standard pterional approach.

FIG. 2. Upper: Schematic drawing representing the extent of removal of the ACP after its separation between the dura and orbital roof. Lower: Schematic drawing showing the anatomical structures after removal of the ACP. The area extends from the optic nerve medially to the lateral margin of the dural insertion into the superior orbital fissure.
Results

Clinoidectomy was successful in all cases, resulting in satisfactory mobilization of the optic nerve and the ICA.

Complications of Treatment

A poor clinical outcome occurred in only one patient, who underwent clipping of a basilar tip aneurysm and suffered thalamic and midbrain infarctions. Ischemia in the territory of the thalamoperforating arteries was presumably induced either by operative trauma to these vessels or by hypoperfusion caused by prolonged application of a temporary clip in combination with artificial hypotension.

Three patients with basilar tip aneurysms had transient oculomotor paresis resulting from intraoperative manipulation of the oculomotor nerve. This cannot be considered a complication of the clinoidectomy.

In four patients, a paranasal sinus was opened during the clinoidectomy (two extradural and two intradural) and the openings were repaired with a strip of muscle, oxycel lulose, and fibrin glue. One patient whose ethmoid sinus was opened developed rhinorrhea that required surgical repair.

One patient (Case 16) with an ICA–OA aneurysm underwent surgery that included an extradural clinoidectomy and she developed quadrantanopsia. This was considered to have been caused by operative manipulation of the OA, rather than by the clinoidectomy. Two additional patients (Cases 24 and 40) suffered a diminution in visual acuity and/or a visual field defect on the side of an extradural clinoidectomy.

No patient suffered perforation of the ICA or aneurysm rupture during clinoidectomy.
Discussion

Anatomy of the ACP and Surrounding Structures

The anatomy of the ACP and surrounding structures has been extensively studied.7,8,11,15 According to the definition of Inoue, et al.,7 the ACP is located at the medial end of the lesser wing of the sphenoid bone and forms the lateral wall of the intracranial end of the optic canal.

The space obtained by removing the ACP is called the clinoid space or area.7,21 The floor of this space is the superior wall of the cavernous sinus. Although lesions in this space have been described erroneously as intracavernous, the space is actually interdural and not located in the cavernous sinus.7,14,17,21

The optic sheath is situated medially and the superior orbital fissure laterally in relation to the clinoid space. The paraclinoid or clinoid segment of the ICA, that is, the segment between the proximal and distal dural ring of the

Fig. 5. Drawings showing how the operative field (shaded portion) is enlarged by cutting the optic sheath, the dural ring, and the cavernous sinus, and by moving the dural fold laterally after removal of the clinoid process.

Fig. 6. Photograph showing that the left ACP has been drilled in this latex-injected cadaver specimen. A vein (arrow) is seen within the ACP. 1 and 2: ACP (undrilled portion); 3 and 4: optic nerve.
ICA, is embedded in this space (Figs. 6 and 7). The ante-
rior cavernous sinus space, which is a real venous space,
is situated inferolateral to the clinoid space. The clinoid space is separated from the cavernous si-
nus by a thick dural membrane. The deep layer of dura
may be incomplete, however, and complete removal of the
ACP may thus result in bleeding from the sinus, even
though the clinoid space is extracavernous. Furthermore,
the ACP itself contains rich venous channels that proba-
bly communicate with the cavernous sinus (Fig. 5). These
facts explain why profuse venous bleeding may occur
when the ACP is removed, as mentioned earlier.

Surgical Approaches

Removal of the ACP permits better mobilization of the
optic nerve and the ICA and yields additional room for
dealing with neighboring structures and lesions. A tech-
nique of intradural clinoidectomy has already been de-
scribed in detail. Although the intradural technique has
the advantage of allowing a direct view of important sur-
rounding intradural structures, it also carries the risk that
the drilling burr will make direct contact with these struc-
tures, including the optic nerve, ICA, and intracranial aneu-ysms; therefore, it is not always safe.

Our selective extradural clinoidectomy can be consid-
ered a modification of the extensive extradural technique
already reported. The lateral and superior wall of the en-
tire optic canal is unroofed and some of the optic strut is
also removed so that the medial margin of the superior
orbital fissure is exposed. The whole anteromedial trian-
gle is exposed in this way. However, the area of drilling is
limited to the region of the ACP; the orbital roof and the
orbital wall lateral to the superior orbital fissure remain
intact.

Extradural clinoidectomy has several advantages over
intradural clinoidectomy. First, anatomical orientation is
easily attained by identifying the dural extension into
the superior orbital fissure and the optic canal, and, there-
fore, an extensive removal is possible. In contrast, when
the intradural technique is used, both the extent of bone
removal and the exposure that is gained tend to be limit-
ed. Second, the dura protects the intradural structures.
Third, the procedure can be performed much more quick-
ly than the intradural technique, because of the greater del-
icacy involved in performing the latter safely.

We believe that most supra- and parasellar lesions are
optimally managed by using our selective extradural an-
terior clinoidectomy. If there is apprehension about the
exact location of intradural structures that are at risk of
being injured, one may open the dura once, check the
anatomical structures around the clinoid process intra-
durally, and then return to perform the extradural clinoi-
dectomy. In our experience, more extensive extradural
techniques involving removal of the orbital rim and/or
zygomatic arch are only required in the treatment of un-
usually extensive lesions and are seldom necessary in ordi-
nary cases.

Treatment Complications

The reported complications of ACP removal include
opening of the paranasal sinus and consequent rhinorrhea,
visual disturbance, oculomotor paresis, injury to the optic
nerve or ICA, occlusion of the OA, rupture of the an-
eurysm, and pneumocephalus.
In our series, the major complication of extradural clinoidectomy was postoperative diminution of visual acuity or visual field defect, which occurred in three cases and was likely due to an injury to the optic nerve during the unroofing of the optic canal or subsequent manipulation. Contraction of the lower half of the visual field is considered to be directly related to the drilling procedure. Opening of a paranasal sinus is another complication, which may easily be repaired with muscle strips, oxycelulose, and fibrin glue. Opening of a sinus may be unavoidable when the ACP is pneumatized. Damage to the clinoid segment of the ICA was not observed in our series.

Conclusions
Extradural removal of the ACP is superior to intradural removal in most cases and can be used routinely for most supra- and parasellar aneurysms and tumors, with minimal complications.

References

Manuscript received November 26, 1996. Accepted in final form May 7, 1997. Address reprint requests to: Yasuhiro Yonekawa, M.D., Department of Neurosurgery, University Hospital of Zürich, Rämistrasse 100, CH-8091 Zürich, Switzerland.