A Transcervical Transclival Approach to the Ventral Surface of the Brain Stem for Removal of a Clivus Chordoma*

GEORGE C. STEVENSON, M.D., RONALD J. STONEY, M.D., ROLAND K. PERKINS, M.D., AND JOHN E. ADAMS, M.D.

Divisions of Neurological Surgery and Otorhinolaryngology and Department of Surgery, University of California Medical Center, San Francisco, California

Because of the surgical inaccessibility and resistance to radiotherapy of clivus chordomas, the prognosis for patients with this lesion has generally been hopeless.1, 6, 10, 18, 22, 24, 25, 29, 34, 37 Non-surgical treatment of clivus chordomas with radium therapy7 and by stereotactic placement of yttrium 9060 has been reported, but surgical removal of the tumor, although usually incomplete, seems to be the best means of palliating clinical symptoms.

Previous surgical approaches to clivus chordomas include a transseptal sphenoidal route,3 a transnasal route,44 an intraoral excision,11 a transoral approach with resection of the lower jaw and soft palate,36 a transoral transpalatal approach,38, 40 and a subtemporal or subparieto-occipital exposure with tenetorial splitting.4, 44, 49, 57 Because these approaches are so often accompanied by meningeal infection21, 38 and occasionally by serious hemorrhage,21 an approach through the neck would be more desirable.

During recent studies in our laboratory on the cerebral blood flow in the isolated intracranial circulation in monkeys, we needed to ligate the basilar artery. This was accomplished by the anterior surgical approach through the clivus described by White and Albin.55 The ease with which this procedure was accomplished when aided by micro-instrumentation (Zeiss dissecting microscope) suggested a possible clinical use. Accordingly, we investigated the possibility of a similar transclival operation in man by dissecting 33 cadavers and by anatomical observations in living patients during radical neck operations for cancer. These preliminary studies enabled us to remove a clivus chordoma employing a transcervical exposure of the clivus through a retropharyngeal approach which has not to our knowledge been previously attempted.

Case Report

A 20-year-old man was seen at the University of California Medical Center, San Francisco, on February 14, 1963, complaining of garbled and slurred speech, dysphagia with nasal regurgitation, drooping from the mouth while sleeping, intermittent diplopia, and uncontrollable, inappropriate laughter, all of 4 months' duration.

Examination. Neurological examination revealed hyperactive jaw reflexes, depression of the right corneal reflex, absent gag reflexes bilaterally, a poorly functioning palate with only slight movement on the right, absent superficial abdominal reflexes on the right and hyperactivity of the right deep tendon reflexes. There was marked weakness of the right biceps and triceps and of the wrist extensors and small muscles of the right hand. A right extensor toe sign was present.

A pneumoencephalogram demonstrated posterior midline displacement of the 4th ventricle with posterior displacement of the aqueduct (Fig.

Received for publication May 10, 1965.

* Presented at meeting of the Harvey Cushing Society, New York, April 12, 1965.

Fig. 1. Pneumoencephalogram. The aqueduct and fourth ventricle are markedly displaced posteriorly.
tion; closed two the submandibular tracheostomy rest.

6). The cerebrospinal fluid protein was 30 mg.
per cent. A vertebral arteriogram showed that the basilar artery was slightly displaced posteriorly in its distal portion (Fig. 2) and displaced in a concave manner to the left of the midline (Fig. 3). Tomograms of the clivus revealed no abnormalities. The tentative diagnosis was pontine glioma.

Preoperative Course. In November, 1963, a posterior fossa myelogram demonstrated a bilobular filling defect projecting into the subarachnoid pontine cistern at a level corresponding to the location of maximal displacement of the basilar artery (Fig. 4). On June 15, 1964, for the first time, tomograms of the skull and clivus demonstrated bony destruction along the superior margin of the clivus behind the posterior clinoid process (Fig. 5). These findings were suggestive of chordoma or clival meningioma.

Radiation therapy was begun on July 9, 1964. During the next 2 months the patient received a total of 5000 r midplane without clinical benefit. He was bedridden when readmitted to the hospital on October 25, 1964. The relentless downhill course had continued and he had been unable to work for several months.

Neurological examination revealed, in addition to the previous findings, evidence of bilateral involvement of the 5th through the 12th cranial nerves. Horizontal nystagmus, which had first appeared 5 months previously, was pronounced, and was accompanied by vertical nystagmus on upward gaze. There was a severe right spastic hemiparesis; plantar responses were bilaterally extensor.

A posterior fossa craniotomy performed on October 28, 1964, revealed an extrinsic prepontine lesion. Only a small lateral extension of the tumor could be visualized and biopsied, establishing the diagnosis of chordoma. In view of the inaccessible location of the lesion, a transcervical transclival surgical exposure of the ventral aspect of the pons was performed 3 weeks later as a last hope for possible tumor extirpation.

Transcervical approach. The transcervical route to the clivus requires meticulous dissection in a confined area if one is to avoid injury to vital structures. The patient's head was rotated 20 degrees to the left and hyperextended 15 degrees to alter the relationship of the mandible to the cervical spine and thereby increase the space in the submandibular and parapharyngeal regions (Fig. 6). The head was rigidly held in the tong head rest. General anesthesia was given through a tracheostomy that was carefully walled off from the operative field. The use of a tracheostomy had two major advantages: (1) the jaws could be closed tightly thus providing greatest access to the submandibular area without mandibular resection; (2) intubation of the larynx and pharynx.

FIG. 2. Vertebral arteriogram. The basilar artery is displaced slightly from the clivus.

FIG. 3. Vertebral arteriogram. The basilar artery is bowed to the left. Slight upward displacement of the proximal right superior cerebellar and posterior cerebral arteries is noted.
Enlargement of the submandibular region was facilitated by dissection of the submaxillary triangle with retraction of the submaxillary gland. The musculature was removed from the right lateral hyoid, which was then resected between the greater and lesser cornua. This allowed medial retraction of the soft tissues beneath the mandible.

The pretracheal fascia was incised between the trachea and the carotid sheath (Fig. 8). Dissection along the lateral aspects of the larynx and hypopharynx allowed palpation of the anterior surfaces of the cervical vertebrae. After the pharynx was retracted medially, a plane between the buccopharyngeal fascia and the prevertebral fascia was developed by blunt dissection (Fig. 8) and carried superiorly to the attachment of the superior pharyngeal constrictor muscle on the pharyngeal tubercle. (The pharyngeal tubercle lies on the clivus 2 cm. anterior to the rim of the foramen magnum.) This maneuver opened the retropharyngeal space.

Enlarging the available retropharyngeal space was accomplished by entering the lateral pharyngeal space which is situated posterolateral to the palate and nasopharynx and contains only fatty tissue. Additional lateral enlargement of this exposure then encroached on the parapharyngeal space through which pass the internal carotid artery, the internal jugular vein, the styloid process, and the glossopharyngeal, vagus, spinal accessory, hypoglossal and sympathetic nerves.

with thick-walled tubes was avoided, facilitating later retraction of those structures.

A curvilinear submandibular skin incision was made from the mastoid tip to the symphysis menti. A "T" extension was carried out from the midpoint of this incision inferiorly across the sternocleidomastoid muscle to the level of the 6th cervical vertebra (Fig. 7). Subplatysmal skin flaps were elevated and the superficial layer of deep cervical fascia was incised parallel to the anterior border of the sternocleidomastoid muscle. The common carotid artery was mobilized and encircled with plasma tubing. The superior thyroid and lingual arteries were divided at their origins from the external carotid artery, and the hypoglossal nerve was identified and mobilized from the level of the styloid process forward to the mylohyoid groove. The underlying internal carotid artery was then mobilized to the point where it entered the base of the skull.

Fig. 4. Pantopaque myelogram. A bilobular filling defect projects into the pontine cistern, each lobule measuring approximately 2 cm. in diameter. One of these lobular densities is in midline and corresponds to the location of the maximum displacement of the basilar artery. Adjacent and contiguous lobular defect is slightly to the right of midline. Arrow indicates basilar artery.

Fig. 5. Lateral tomogram of the clivus. The cortical margin of the superior portion of the clivus is demineralized.
By dividing the fascial band running from the styloid process to the posterior pharyngeal wall, this parapharyngeal space was widened. (An elongated styloid process may be fractured if necessary.) Lateral retraction of the carotid artery, internal jugular vein, and cranial nerves then exposed the atlas and axis still covered by the prevertebral fascia and cervical musculature.

Further retropharyngeal exposure was achieved by dissection anterior and superior to the pharyngeal tubercle. A subperiosteal elevation of the pharyngeal mucosa was carried rostrally over the clivus until the vomer could be palpated. This exposed the ventral aspect of the clivus itself. Rostral dissection was terminated at this point to prevent injury to the pharyngeal mucosa or inadvertent entry into the nasopharynx. A deep-bladed retractor was used to elevate the nasopharynx with the blade of the retractor resting on the clivus (Fig. 9). Palpation of the right and left angular spines of the greater wing of the sphenoid indicated that the dissection ended just rostral to a line connecting the two spines. Carrying the dissection this far rostrally ensured that the blade of the retractor, 3 cm. in width, would not injure the internal carotid arteries as they entered the skull.

The prevertebral fascia was opened in the midline from the anterior rim of the foramen magnum inferiorly over the arch of the atlas down to the 3rd cervical vertebra. Subperiosteal dissection of the cervical musculature allowed elevation and lateral retraction of the rectus capitis anterior, longus capitis, and longus colli muscles. The medial pterygoid plate was palpated on each side to determine the limits of retraction possible. A small self-retaining retractor was used to maintain lateral retraction of these muscles which exposed the ventral and anterior aspects of the clivus, atlas and axis.

The tongue rest which was maintaining the desired skull-to-cervical spine relationship was repositioned to reduce the hyperextension to 5 degrees and the left lateral rotation to 10 degrees. _Transclival approach._ The anterior arch of the
atlas was penetrated with a Hall drill at distances of 2 cm. to the right and 2 cm. to the left of the midline. The anterior arch of the atlas including the anterior tubercle was then merely lifted out to expose the subjacent odontoid process. The base of the odontoid process was "fractured" with the Hall drill, and division of the lateral alar and apical odontoid ligaments allowed removal of the odontoid process (Fig. 10). Division of the superior portion of the subjacent transverse portion of the cruciform ligament exposed an accessory deep and lateral portion of the tectorial membrane which, when removed, exposed the tectorial membrane and posterior longitudinal ligament.

The preceding portions of the operation were performed under direct vision, the illumination being afforded by a head light. For the remainder of the procedure, the operative field was illuminated and magnified through the Zeiss binocular dissecting microscope (Fig. 9). Utilizing the air drill, a window-like defect was fashioned in the clivus measuring 2 1/2 cm. in lateral transverse diameter and 3 1/2 cm. from the anterior rim of the foramen magnum to just anterior to the sphenoid clinoid synchondrosis.

Superiorly, lateral extension of this clival defect was limited by 2 vascular structures: (1) the internal carotid artery where its petrous portion becomes the intracavernous portion (since the posterior medial wall of the canal housing this portion of the internal carotid artery is also part of the clivus); and (2) the inferior petrosal sinuses lying within the petro-occipital fissure which assumes a more medial position superiorly. Inferiorly, the lateral edge of the clival window was limited by the jugular tubercle which lies medial to the inferior petrosal sinuses. Injury to the sinuses and to the 12th nerve within the hypoglossal foramen was prevented by not extending the edge of the window-like excavation lateral to
the jugular tubercle. Very little bleeding was encountered during the drilling of the cancellous bone of the clivus. The bone appeared normal except for some "scalloping" caused by simple pressure erosion from the chordoma.

The final excavaion in the bone (clival window and odontoid process) (Fig. 11) measured 4 1/2 by 2 1/2 cm.

A grayish-white membrane covering the tumor was believed to be a pseudocapsule rather than dura mater. Removal of the pseudocapsule exposed the inner portion of the tumor which measured approximately 3 by 4 cm. This creamy-yellow mass was soft and gelatinous, yielding easily to removal by suction. The inner capsule (in juxtaposition to the brain stem) was removed with micro-instruments exposing the basilar artery and pial vasculature of the pons.

As more tumor was removed, the displaced basilar artery assumed a more normal midline position and was under direct vision within the prepontine cistern. The dura was not identified; it may have been intimately connected to the capsule of the tumor and so removed, or it may have been destroyed previously by the tumor. In any case, after removal of all visible tumor and capsule, the brain stem appeared in the clival window covered by an intact arachnoidal membrane. A Valsalva maneuver performed by the anesthesiologist at this time revealed no leakage of cerebrospinal fluid.

To prevent postoperative loss of cerebrospinal fluid, stamp grafts of sternocleidomastoid muscle were placed in the clival window defect, supported by a "hammock" of Surgicel gauze. The prevertebral musculature (the longus colli and longus capitis muscles) and fascia were reunited in the midline with interrupted sutures. The superior pharyngeal constrictor muscle was then sutured to the prevertebral fascia at the level of the anterior rim of the foramen magnum. The buccopharyngeal fascia was sutured to the prevertebral fascia to obliterate the retropharyngeal space. The soft tissue of the neck and the trachea and pharynx were allowed to fall together. The superficial layer of deep cervical fascia, platysma, and skin were closed with interrupted silk sutures. A foam rubber pack was placed in the nasopharynx as a stent to help ensure approximation of the superior pharyngeal constrictor muscle and the buccopharyngeal fascia against the basiocciput and the prevertebral fascia.

In a further effort to prevent the postoperative leakage of cerebrospinal fluid, the patient was (1) immobilized with Crutchfield tongs and sand bags to prevent lateral movement of the head with associated movement of the pharynx on the prevertebral surface, and (2) maintained in a 45-degree head-elevated position. Continuous spinal drainage was maintained by an indwelling catheter in the lumbar subarachnoid space.

Postoperative course. By the end of the first postoperative week, neurological improvement was apparent, manifested by disappearance of the right 6th nerve palsy and by an increase in strength of the proximal muscles of the right arm and leg. One month after operation, the patient had regained full use of his right arm. The horizontal nystagmus on lateral gaze was considerably less, and the nystagmus on vertical gaze had virtually disappeared.

The last follow-up examination, 8 months after operation, showed disappearance of all bulbar and long tract signs. Function of the muscles of the pharynx was normal and the patient had no difficulties in swallowing or handling secretions.
At no time after the operation did he exhibit inappropriate laughter. The patient has been discharged from the hospital and is working at his previous job.

Because postoperative cinefluorographic studies of the cervical spine revealed no significant instability, a planned atlanto-axial fusion was not done.

**Possible Application**

This transcervical transclival craniotomy approach may have application in the treatment of many extracerebral neoplasms situated anterior to the brain stem.\(^{36,46}\) Even if total extirpation of a lesion such as a clival or foramen magnum meningioma\(^5,9,15,29,32,39,59\) or chordoma\(^{4,13,34,36,48}\) is not feasible, decompression of the brain stem can be accomplished through the clival defect.

The development of a transcervical approach to the clivus eliminates the hazards of infection which vitiate the use of the transseptal sphenoïdal, transnasal, and transoral transpalatal operative exposures. The suboccipital craniectomy exposure has long been acknowledged as inadequate for the treatment of clivus chordoma. While the classical temporal craniotomy exposure in conjunction with splitting of the tentorium may still have a place in the treatment of preptontine lesions immediately posterior to the dorsum sellae, it is not adequate for the treatment of lesions situated further caudally (i.e., on the clivus and at the anterior rim of the foramen magnum). The present transcervical transclival craniotomy approach provides a direct exposure of the ventral aspects of the foramen magnum, clivus, pons, and medulla. In addition, this exposure does not require retraction of the medulla, pons, and cerebellum (as is done during a suboccipital craniotomy) or cutting of the trigeminal nerve (as is required by the tentorial splitting procedures).

This operation can also be used to relieve compression of the brain stem caused by a number of other disorders: posterior fossa aneurysms;\(^2,12,14,18,19,30,32,33,49–52,56\) fracture-displacement of the odontoid;\(^1,10,23,27,33,41,42\) occipitalization of the atlas;\(^29\) basilar impression;\(^5,48,56\) os odontoideum;\(^17,25,36,47\) chronic atlanto-axial dislocations;\(^20\) and odontoid osteochondromas.\(^46\) Additionally, the transcervical portion of this procedure, by exposing such a rostral extent of the retropharyngeal and parapharyngeal areas, may have clinical importance for the removal of neoplasms located in those areas.

**Summary**

A transcervical transclival exposure of the ventral aspect of the brain stem has been performed for the first time in man and permitted successful removal of a clivus chordoma. We have presented details of the technique and discussed other applications of this approach.

**References**

15. Dany, A., Delcoh, J., and Laîne, E. Les méningiomes du clivus. Étude clinique, radio-
Transclival Approach to Ventral Brain Stem


35. Kratzenbrink, H. Personal communication.


38. Mayfield, F. H. Personal communication.


40. Mullan, S. Personal communication.


44. Olevichona, H. Personal communication.

45. Poppens, J. L. Personal communication.


