The Journal of
Laryngology and Otology

(*Founded in* 1887 *by* MORRELL MACKENZIE *and* NORRIS WOLFENDEN)

November 1978

Infratemporal fossa approach to tumours of the temporal bone and base of the skull*

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IN spite of the translabyrinthine and middle cranial fossa approaches, tumours situated in the infralabyrinthine and apical regions of the pyramid and surrounding portions of the base of the skull remain a surgical challenge for neurosurgeons and otolaryngologists as well. The transpalatal-transpharyngeal route proposed by Mullan *et al.* (1966) and the trans-cochlear approach of House and Hitselberger (1976) do not provide adequate exposure for large glomus jugulare tumours, clivus chordomas, cholesteatomas and carcinomas invading the pyramid tip and skull base. The proper management of these lesions requires a larger approach permitting exposure of the internal carotid artery from the carotid foramen to the cavernous sinus (Fig. 1). The infratemporal fossa exposure presented in this paper is a possible solution to this problem. The basic features of the proposed lateral approach to the skull base are: (a) the permanent anterior displacement of the facial nerve, (b) the subluxation or permanent resection of the mandibular condyle, (c) the temporary displacement of the zygomatic arch, and (d) the subtotal petrosectomy with obliteration of the middle ear cleft. *Three different types* of infratemporal fossa approach have developed from the experience gained in 51 patients. They will be described and illustrated with typical cases.

Surgical technique

The realization of the infratemporal fossa approach to the pyramid tip and base of the skull has been hampered by difficulties in handling the following structures (Fig. 2): (a) the facial nerve, (b) the mandibular

* Based on the Toynbee Memorial Lecture delivered at the Royal College of Surgeons on 4 May 1978.

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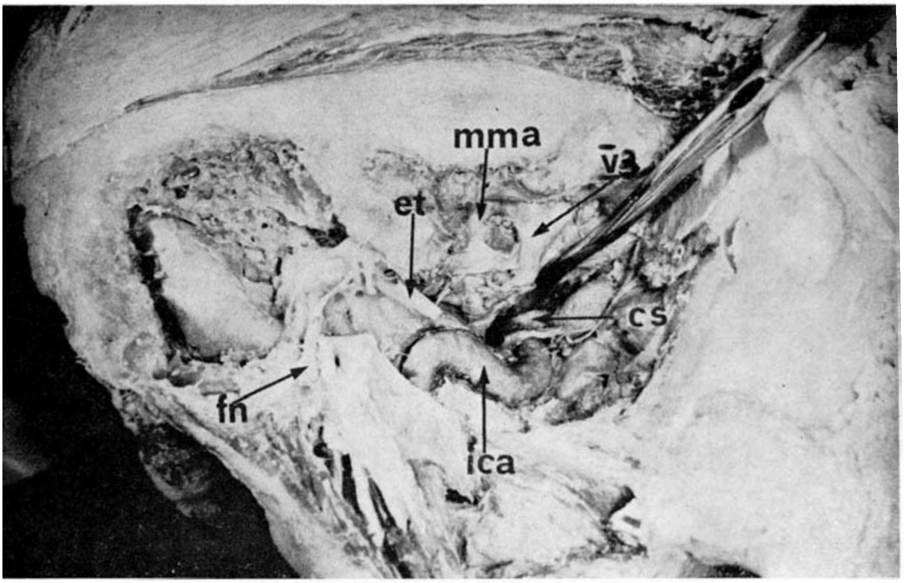

FIG. 1

Exposure of the intratemporal portion of the internal carotid artery (ICA) through the infratemporal fossa (cadaver preparation). Note that the facial nerve (FN), the middle meningeal artery (MMA) and the mandibular division of the trigeminal nerve (V_3) have been cut and the ascending mandibular ramus, the zygomatic arch and the Eustachian tube (ET) have been removed for the sake of exposure.

condyle, (c) the zygomatic arch, (d) the Eustachian tube, (e) the middle meningeal artery, and (f) the mandibular and eventually the maxillary division of the trigeminal nerve. Only by displacing or removing these structures can one expose the whole of the intratemporal course of the carotid artery via the infratemporal fossa. The experience gained with 51 patients operated upon between January 1970 and August 1976 has shown that three different types of infratemporal fossa approach are of practical interest (Fig. 3):

1. Type A gives access to tumours of the infralabyrinthine and apical compartments of the temporal bone.
2. Type B is mainly used for lesions involving the clivus and invading the base of the skull along the Eustachian tube.
3. Type C has to be used for tumours originating in the parasellar region.

These different types of infratemporal fossa approach will be described in detail and illustrated separately by typical cases.

1. *Infratemporal fossa approach for tumours of the infralabyrinthine and apical compartment of the temporal bone* (*Type A*)

For this approach the skin incision is carried out as for an extended parotidectomy with an additional postauricular limb (Fig. 4). The facial nerve with its main branches as well as the main vessels and nerves of the neck are then exposed

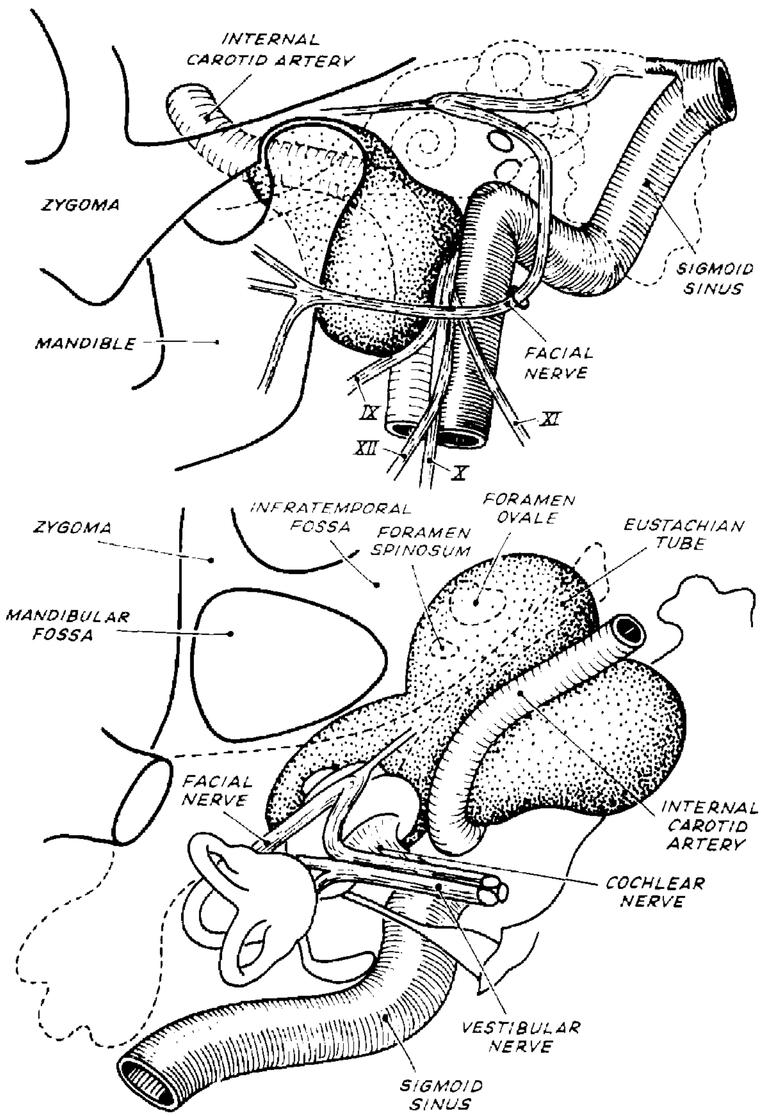

FIG. 2

The anatomical structures preventing lateral access to the infratemporal fossa are: 1. the facial nerve; 2. the mandibular condyle; 3. the zygomatic arch; 4. the Eustachian tube; 5. the middle meningeal artery (foramen spinosum); and 6. the mandibular division of the trigeminal nerve (foramen ovale).

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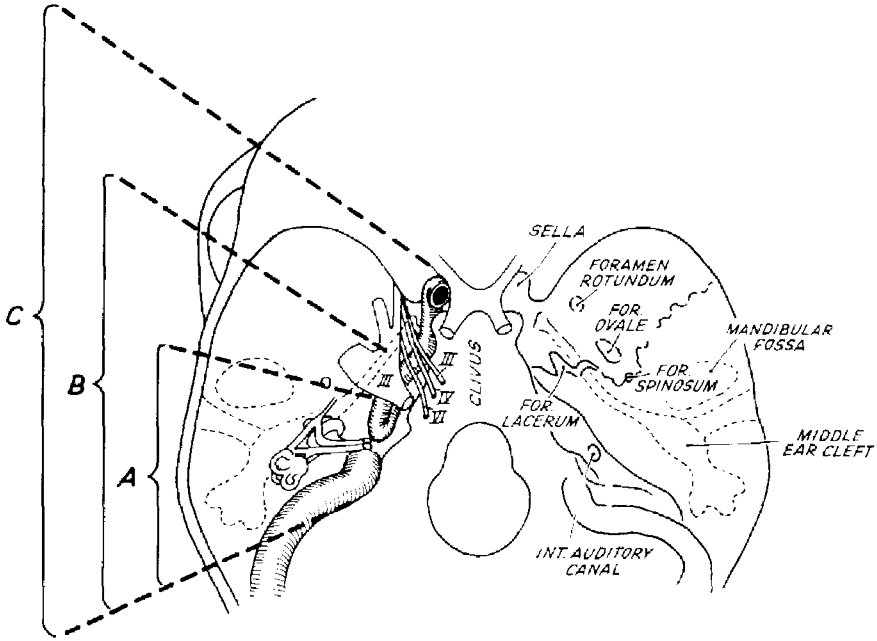

FIG. 3

The three types of infratemporal fossa approach.
Type A gives access to the infralabyrinthine and apical compartments of the temporal bone, type B to the clivus, and type C to the parasellar region.

(Fig. 5). The external carotid artery is ligated distal to the lingual branch to minimize hemorrhage in the infratemporal region. The auricle is separated from the temporal bone by cutting through the cartilagenous external auditory canal and secured superiorly with silk sutures. The skin of the external auditory canal is removed in one piece with the tympanic membrane and malleus handle. A radical mastoidectomy is performed exposing the tympanic and mastoid segments of the Fallopian canal. If inner ear function is intact, the superstructure of the stapes and the whole of the middle ear mucosa are removed.

Usually at this stage the infralabyrinthine extension of the tumour becomes visible in the hypotympanum. The facial nerve is exposed from the stylomastoid foramen to the geniculate ganglion. A groove is created in the anterior epitympanum between the geniculate ganglion and the root of the zygoma. The facial nerve is then lifted out of its bed in its parotid, mastoid and tympanic portions and transposed anteriorly into the newly created bony groove of the epitympanum (Figs. 5 and 6). This manœuvre gives free access to the jugular bulb, carotid foramen and isthmus of the Eustachian tube. In case of involvement of the jugular bulb the sigmoid sinus is doubly ligated cephalad to the tumour (Fisch, 1976, 1977). In view of the gain in length of the VIIth nerve obtained by its anterior transposition, the ascending mandibular ramus is displaced anteriorly (Fig. 5) thus exposing the stylohyoid process and tympanic bone. In the case of a large anterior extension of the tumour, the mandibular condyle is resected for better

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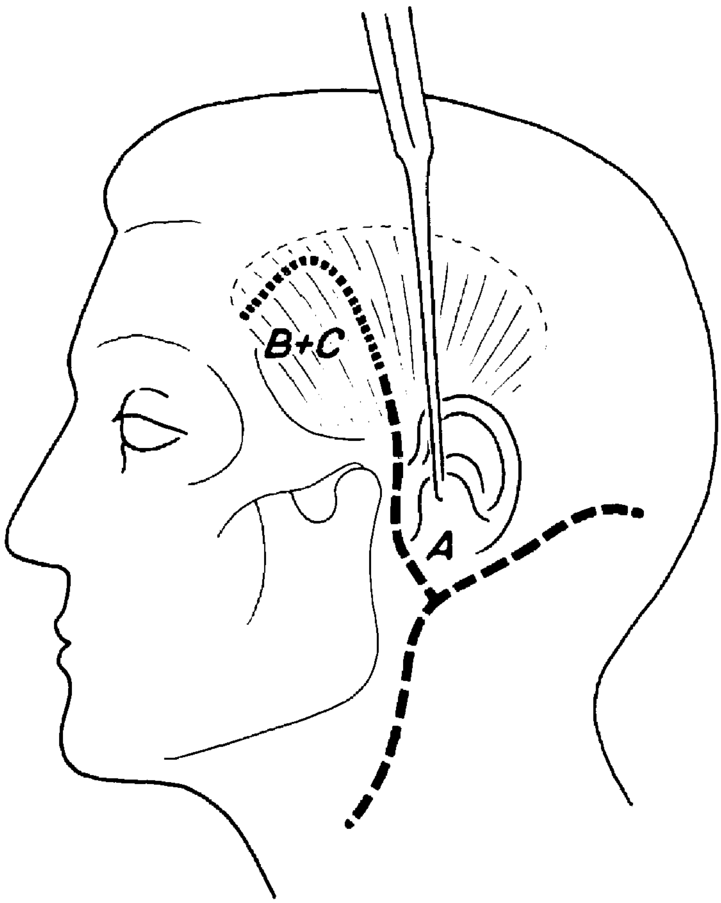

FIG. 4
Skin incision for the infratemporal fossa approach. Longer line: skin incision for type A approach. Long and short lines: skin incision for type B and C approaches.

access (Fig. 6). After drilling away the styloid process and tympanic bone, the dissection is carried anteriorly, exposing the internal carotid artery inside the carotid canal. This requires partial destruction of the bony walls of the Eustachian tube. At this stage the well-visualized anterior pole of the tumour can be dissected from the carotid wall and separated from the infralabyrinthine bone, exposing the posterior fossa dura at the medial aspect of the temporal bone, just above the jugular foramen. Bleeding from the inferior petrosal sinus usually occurs and is stopped by packing with free muscle grafts or oxycel. The inferior pole of the tumour is then lifted laterally following eventual proximal ligation and transection of the invaded internal jugular vein. An attempt is made to separate the hypoglossal, glossopharyngeal, vagus and accessory nerves from the medial portion of the tumour. After this the posterior extension of the lesion is mobilized and removed with the whole of the lesion.

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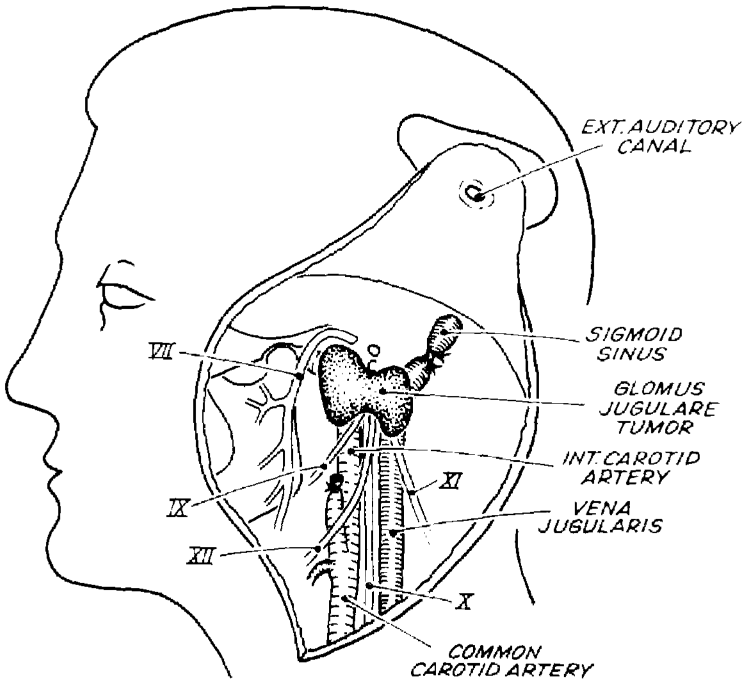

FIG. 5

Surgical site illustrating type A infratemporal fossa approach to tumours of the infralabyrinthine space and pyramid tip. Note the double ligature of the sigmoid sinus, the permanent displacement of the VIIth nerve and the anterior subluxation of the mandibular condyle. The anterior extension of the tumour is well visualized.

When there is extensive dural infiltration the intracranial portion of the tumour is left in place and will be extirpated by the neurosurgeon in a separate procedure (if this has not yet been done).

Following removal of the tumour the tympanic end of the Eustachian tube is occluded with bone paste (bone dust mixed with bone wax) and a free musculofacial graft (Fig. 7). The external auditory canal is then closed as a blind sac and the posterior portion of the temporalis muscle is routed down into the temporal cavity to obliterate dead space. Free abdominal adipose grafts are added if necessary without danger of compressing the anteriorly displaced facial nerve.

Comment: The typical features of the type A infratemporal fossa approach are: (a) permanent anterior displacement of the facial nerve, and (b) permanent obliteration of the pneumatic middle ear spaces. Usually there is no need to remove the mandibular condyle since sufficient access is gained by simple subluxation of the temporo-mandibular joint. The advantages of permanent displacement of the facial nerve versus limited temporary mobilization of its intratemporal tympanic and mastoid segments (as proposed e.g. by House and Hitselberger, 1976; H. L. and S. Wullstein, 1976) are: (a) unhampered surgical manipulations along the

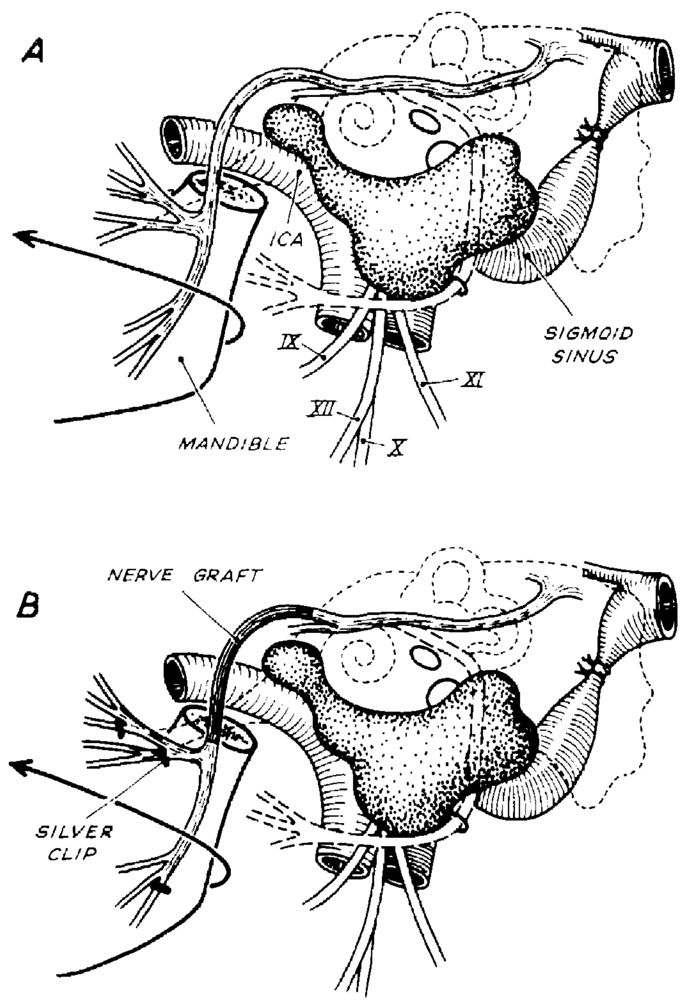

FIG. 6

Infratemporal fossa approach (type A) for extensive tumours of the infralabyrinthine and apical compartments of the temporal bone.

A: Adequate exposure of the inferior and anterior poles of the tumour is obtained by the permanent anterior transposition of the facial nerve and by the resection of the mandibular condyle. Note the double ligature of the sigmoid sinus.

B: Anterior permanent displacement of the facial nerve is also used when a segment of the nerve has to be replaced by a nerve graft because of intraneural tumour invasion. In this way a good vascular bed is supplied to the nerve graft and compression of the operative cavity will not affect the regeneration of facial nerve motor fibres.

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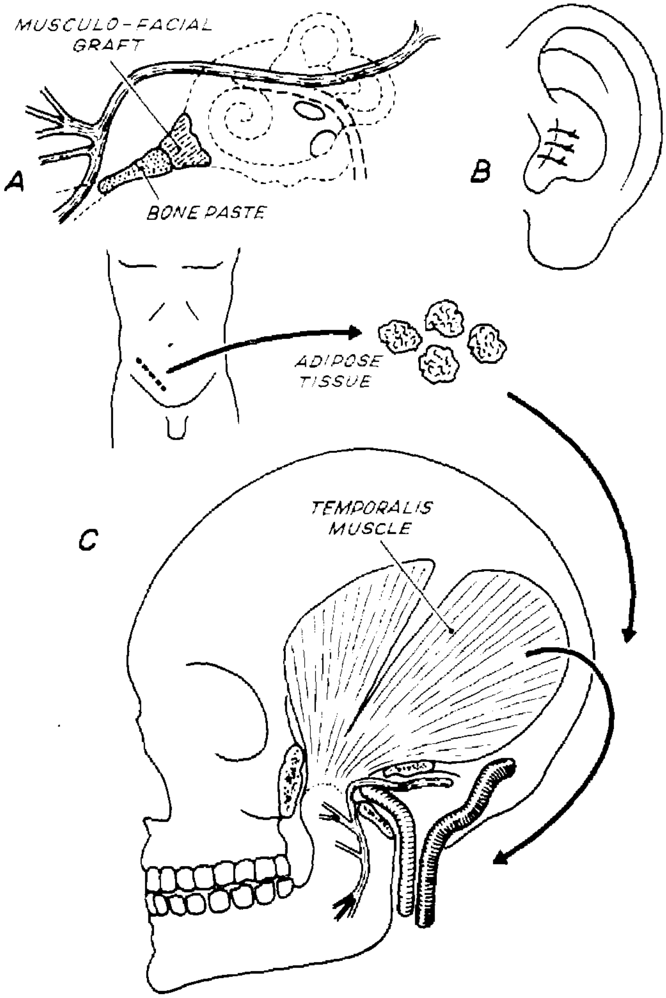

FIG. 7

Following total tumour removal, the obliteration of the middle-ear cleft is accomplished by:
A: Permanent obliteration of the Eustachian tube with bone wax and free musculo-facial grafts.
B: Blind sac closure of the external auditory canal.
C: Filling of the surgical cavity with temporalis muscle and lipodermal grafts from the abdominal wall.

jugular bulb, internal carotid artery and pyramid tip during tumour removal, (b) the possibility of packing the operative cavity (particularly the inferior petrosal sinus) without fear of undue compression of the VIIth nerve following tumour removal. The sacrifice of the Eustachian tube is necessary in order to expose the intratemporal course of the internal carotid artery. In view of the resulting irreversible loss of tubal function, complete obliteration of the pneumatized middle-ear spaces is mandatory. This is accomplished by performing what we call a *subtotal petrosectomy*. This procedure consists in an extended radical operation leading to the exenteration of the temporal bone with the exception of the inner ear capsule and of the cortical layer surrounding the dura of the middle and posterior cranial fossae. Excision of the stapes superstructure prevents inadvertent luxation of this ossicle during surgical manipulations along the tympanic segment of the facial nerve or when packing the operative cavity.

The *advantages* of the type A infratemporal fossa approach can be summarized as follows: (a) wide access to the infralabyrinthine and apical portions of the temporal bone with exposure of the entire intratemporal course of the internal carotid artery; (b) no injury of the permanently transposed facial nerve during tumour extirpation and when packing the operative cavity; and (c) avoidance of an open cavity and therefore of the danger of a postoperative meningitis when the subarachnoid space has been entered during surgery (as e.g. for ligation of the sigmoid sinus).

The main *disadvantage* of the approach is the conductive hearing loss resulting from the obliteration of the middle ear cleft.

The following two cases will illustrate the use of the surgical technique described above.

Case 1: A 19-year-old woman suffered from a progressive right-sided hearing loss and pulsating tinnitus for 5 years and from diplopia and unsteadiness for 6 months. She was seen in March 1970 at the Neurosurgical Department of the University of Zürich following which a ventricular shunt was carried out to relieve an apparent obstructive hydrocephalus. In April 1970 the right cerebellopontine angle was explored via a suboccipital approach and the intracranial extension of a large glomus jugulare tumour was resected at the jugular foramen. The patient was referred to us in May 1970. Neurological examination revealed a right abducens palsy, absence of a gag reflex and a right hypoglossal palsy with atrophy of the right side of the tongue. Polytomography demonstrated a large inferior defect in the right temporal bone extending to the apex of the pyramid. Angiography demonstrated the typical appearance of a type C glomus jugulare tumour* which had destroyed the infralabyrinthine and apical portions of the temporal bone. In May 1970 a type A infratemporal fossa approach was carried out. Through a Y-shaped skin incision around and inferior to the ear, the extratemporal portion of the facial nerve was exposed as well as the internal and external carotid arteries and cranial nerves IX, X, XI and XII. The external carotid artery and the internal jugular veins were both ligated. After radical mastoidectomy the tumour was found to extend underneath the facial nerve to the sigmoid sinus. The basal turn of the cochlea and posterior canal ampulla

* We use the following classification for glomus tumours of the temporal bone: type A = glomus tympanicum tumour; type B = glomus jugulare tumour with no destruction of bone; type C = glomus jugulare tumour with destruction of the infralabyrinthine compartment of the temporal bone; type D = glomus jugulare tumour with intracranial extension.

were destroyed by the tumour. The tympanic and mastoid segments of the facial nerve were mobilized from the Fallopian canal and the VIIth nerve transposed anteriorly into a groove drilled in the epitympanic wall between the geniculate ganglion and the root of the zygomatic arch. The anterior pole of the tumour was found to extend around the internal carotid artery to the pyramid tip. The ascending mandibular ramus was displaced by luxating the temporo-mandibular joint. The internal carotid artery was exposed from the carotid foramen to the apex of the temporal bone, with sacrifice of the bony Eustachian tube. The tumour was then separated from front to back and removed in one piece, thus exposing the dura of the posterior fossa in the infralabyrinthine region following removal of the inferior lateral wall of the sigmoid sinus. Bleeding from the inferior petrosal sinus was controlled with oxycel packing. The still preserved distal portion of the Eustachian tube was occluded with bone paste and a free musculo-fascial graft. The external canal was closed as a blind sac and the surgical cavity filled with abdominal adipose grafts. The patient had an uneventful recovery and was able to leave the hospital 14 days following surgery. The abducens and hypoglossal lesions showed rapid regression and disappeared after six months. The patient has remained free of symptoms up to date more than 8 years following surgery.

Case 2: A 26-year-old woman with a 6 years' history of right-sided deafness, a 4 years' history of pulsating tinnitus and progressive peripheral facial palsy was submitted elsewhere, in December 1973, to a radical mastoidectomy with partial removal of a glomus jugulare tumour. In June 1974 a spell of meningitis was successfully cured with antibiotic treatment. The patient was referred to us in September 1974 with a right facial paralysis and a discharging right radical cavity. Polytomography and angiography showed complete destruction of the inferior half of the temporal bone due to a type C glomus jugulare tumour. In September 1974 radical removal of the tumour was performed through a type A infratemporal fossa approach. Through a Y-shaped incision around and underneath the ear the facial nerve was exposed in the parotid region and the external and internal carotid arteries, internal jugular vein, and the glossopharyngeal, vagus, spinal accessory and hypoglossal nerves were identified in the neck. Following ligation of the external carotid artery the tympanic and mastoid segments of the facial nerve were excised because of tumour infiltration. The sigmoid sinus was ligated and the posterior inferior portion of the tumour, which had reached the endosteum of the basal turn of the cochlea and of the posterior ampulla, was extirpated. In spite of the transcochlear approach the anterior extension of the tumour lying medial, anterior and inferior to the carotid artery could not be adequately exposed. The labyrinthine segment of the facial nerve was then identified and transposed into a groove drilled in the anterior epitympanic wall. The temporo-mandibular joint was subluxated and the ascending ramus of the mandible displaced anteriorly. Following complete removal of the tympanic bone and styloid process the internal carotid artery was followed from the carotid foramen to the apex of the pyramid. The tumour was elevated away from the exposed artery and totally removed, from front to back, by blunt dissection. The dura of the internal auditory canal was infiltrated by the tumour anteriorly and inferiorly. The infiltrated portion of the dura had to be resected and reconstructed with lyophilized dura.* The distal portion of the Eustachian

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tube was closed with bone paste and a musculo-facial graft. The continuity of the facial nerve was reconstructed with a graft from the great auricular nerve, reaching from the anterior epitympanic wall to the nerve stem in the parotid region. The anastomosis were performed using collagen splints and tissue glue (histoacryl). Silver clips were applied to the superfluous peripheral facial nerve branches in order to direct generation in the superior and inferior regions of the face (Fisch, 1974). Blind sac closure of the external auditory canal and filling of the surgical cavity with lipodermis from the abdominal wall was performed. Because of a persistent cerebrospinal fluid leak, the surgical wound had to be revised and a portion of the temporalis muscle was rotated into the operative cavity over the repaired dural defect. Under antibiotic cover (3×8 mg. of Gentamicin and 3×2 g. of Ampicillin intravenously each day) the patient made an uneventful recovery. She is free of symptoms to date (more than 4 years after the operation), and facial movements have recovered 75 per cent.

2. *Infratemporal fossa approach for lesions of the clivus and epipharynx (type B)*

For the type B infratemporal fossa approach the skin incision is carried out as for the type A but with an anterior extension over the temporal region (Fig. 4). In order to gain wider access in the infratemporal fossa the mandibular condyle is resected (Fig. 8). After inferior reflection of the zygomatic arch, the glenoidal fossa of the temporo-mandibular joint is drilled away and the middle meningeal artery and the mandibular division of the trigeminal nerve are severed at the level of the foramina spinosum and ovale. The internal carotid artery is then exposed, from the carotid foramen to the foramen lacerum. The pyramid tip and the clivus are now widely accessible (Figs. 8 and 9). Following tumour removal the Eustachian tube is obliterated and the external auditory canal closed as a blind sac. The entire temporalis muscle is then reflected into the operative cavity, the zygomatic arch is wired in place and the surgical wound is closed in two layers following the introduction of a negative suction drainage.

The main features of the type B infratemporal fossa approach are: (a) permanent anterior transposition of the facial nerve, (b) permanent resection of the mandibular condyle, (c) temporary displacement of the zygomatic arch, (d) permanent destruction of the Eustachian tube with subtotal petrosectomy and obliteration of the middle-ear cleft and (e) division of the middle meningeal artery and of the mandibular division of the trigeminal nerve.

The *advantages* of the approach are: (a) wide access over the entire clivus from the foramen magnum to the sphenoid sinus, without opening of the pharyngeal wall and therefore avoiding contamination of the operative wound, and (b) possible extension to the epipharynx (following partial removal of the pterygoid process), permitting removal of carcinomas invading the pyramid tip along the Eustachian tube. The *disadvantages* are: (a) complete conductive hearing loss due to obliteration of the middle-ear cleft, (b) a slight degree of malocclusion without need of

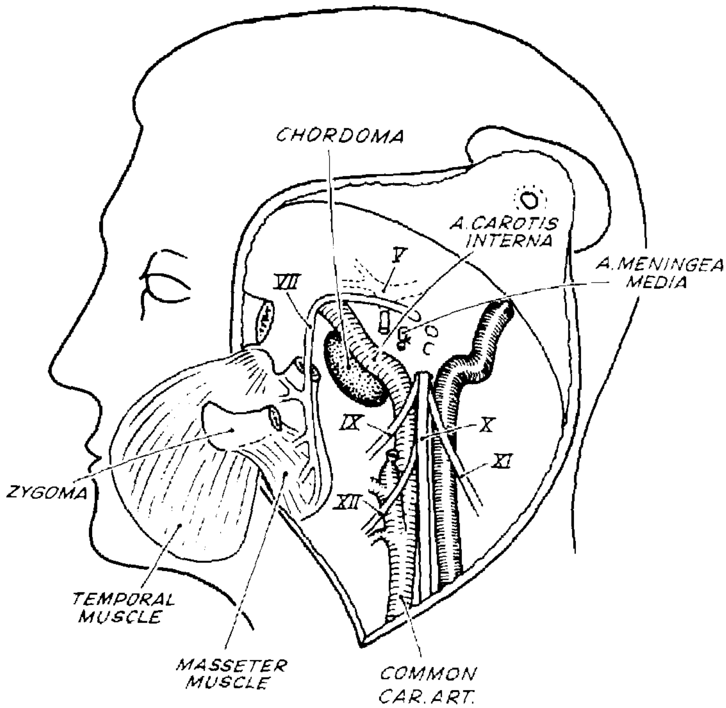

Fig. 8

Surgical site demonstrating the infratemporal fossa approach for tumours of the clivus. Note the exposure of the internal carotid artery from its bifurcation to the cavernous sinus. The mandibular condyle is resected. The zygoma is reflected inferiorly with attached masseter muscle. The permanent anterior transposition of the facial nerve gives a good view over the area of the clivus. The middle meningeal artery and the mandibular division of the trigeminal nerve are divided at the level of the foramina spinosum and ovale.

corrective orthodontic measures due to loss of the mandibular condyle, and (c) loss of sensitivity of the face in the region of the third division of the trigeminal nerve.

The following case illustrates the application of the infratemporal fossa approach type B for removal of a clivus chordoma.

Case 3: A 33-year-old man was seen in November 1976. He gave a two years' history of diplopia because of left abducens nerve palsy. Surgical correction of the left lateral rectus had been performed without success elsewhere. Subsequently the patient developed difficulty in moving the tongue and right-sided headaches. On inspection the bulging epipharyngeal wall was seen to close the right choanal opening. A biopsy taken through the epipharynx gave the pathological diagnosis of chordoma. On neurologic investigation the gag reflex was absent and the pharyngeal wall dropped on the right side. There was a paralysis on the right side of the tongue and of the left abducens nerve. Polytomography

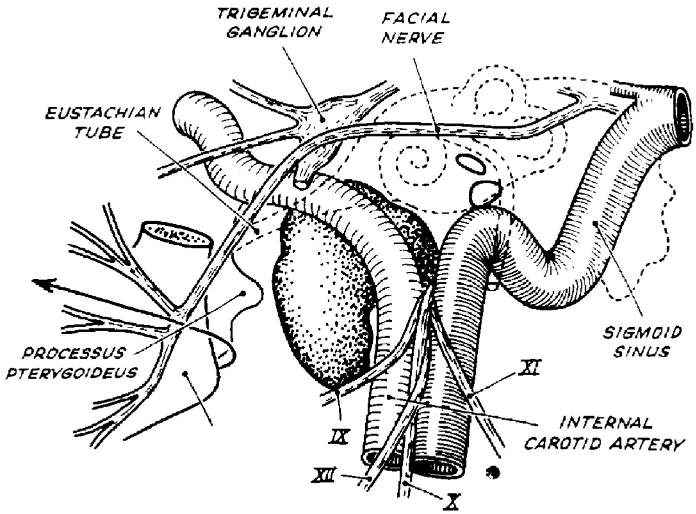

FIG. 9

Infratemporal fossa approach for tumours of the clivus (type B). Note the good exposure obtained by the permanent anterior displacement of the facial nerve, the resection of the mandibular condyle, the temporary reflection of the zygomatic arch, section of the middle meningeal artery and of the mandibular division of the trigeminal nerve. The pterygoid process has to be removed to attain access to the epipharynx.

revealed destruction of the clivus and the right pyramid tip. On angiography the basilar artery was displaced superiorly by the large clival mass. In November 1976 the chordoma was radically removed through an infratemporal approach with subtotal petrosectomy and anterior permanent displacement of the facial nerve. The operation was begun by exposing the facial nerve in the parotid area and the major vessels and nerves in the neck. Following radical exenteration of the pneumatic middle-ear spaces with preservation of the inner ear, the tympanic and meatal segments of the facial nerve were transposed anteriorly into a bony groove drilled in the anterior epitympanic space. The zygomatic arch was displaced inferiorly and the condyle of the mandible resected. The middle meningeal artery and the external carotid artery were ligated and the third trigeminal division sectioned at the foramen ovale. Following removal of the tympanic bone and styloid process the large chordoma involving the total length of the clivus was exposed and removed from the atlas to the pyramid tip and sphenoid bone. The carotid artery had to be temporarily displaced in order to remove eroded portions of the clivus with a diamond drill until normal bone and dura were reached. At the end of the procedure, which was carried out with the operating microscope, the Eustachian tube was obliterated, the external canal closed as a blind sac and the surgical cavity filled with the mobilized temporalis muscle and abdominal fat. The zygomatic arch was repositioned and fixed with wire. The patient made an uneventful recovery and was able to leave the hospital with primary wound healing 12 days after surgery. The post-operative facial weakness disappeared after 6 months. The deficit from the nerves VI, IX, X and XI disappeared after a year. The patient is still free of recurring disease two years after surgery.

3. *Infratemporal fossa approach for tumours of the parasellar region* (*type C*)

For the removal of tumours of the parasellar region the operation progresses as for the type B approach with addition of (a) complete inferior reflection of the zygoma with its orbital process and portion of the lateral orbital rim, (b) temporary section of some (or all) main ramifications of the facial nerve in the parotid area in order to avoid undue traction during exposure, (c) resection of the pterygoid process, (d) exposure and eventual section of the maxillary division of the trigeminal nerve at the level of the foramen rotundum, and (e) lifting of the middle cranial fossa dura in order to expose the carotid artery above the foramen lacerum into the cavernous sinus (Fig. 10). At the end of the procedure the zygoma and lateral wall of the orbit are wired back in their original places. The operative cavity is closed as in the type B procedure.

The *advantage* of this approach is: the wide access over the lateral parasellar space. The *disadvantages* are (a) eventual impairment of facial

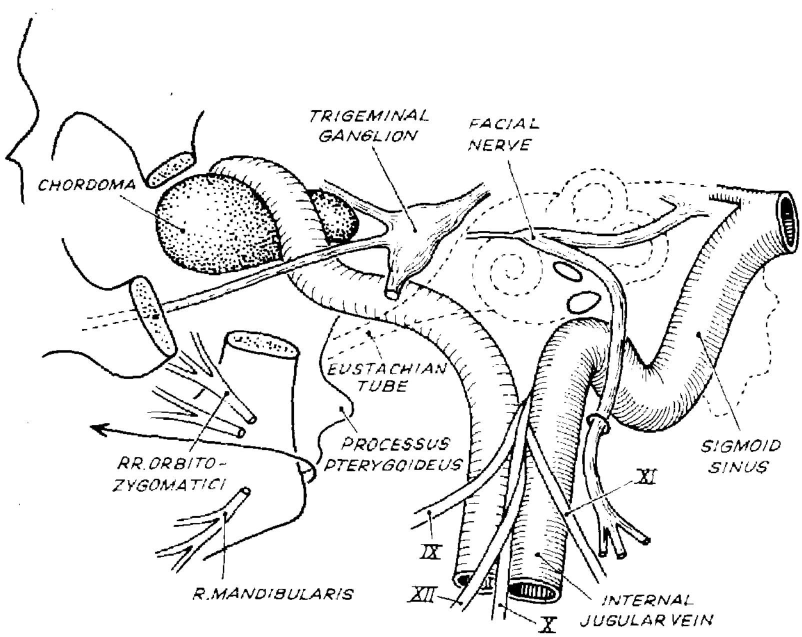

FIG. 10

Infratemporal fossa approach for parasellar and parasphenoid tumours (type C). Adequate access is obtained by resection of the mandibular condyle, reflection of the zygoma and lateral orbital rim, temporary section of the peripheral branches of the facial nerve as well as section of the middle meningeal artery and mandibular division of the trigeminal nerve.

function due to the temporary section of the VIIth nerve or of its main branches, (b) permanent conductive hearing-loss due to the obliteration of the middle ear cleft, (c) minimal malocclusion due to the loss of mandibular condyle and (d) loss of sensitivity of the face due to the section of the mandibular and maxillary divisions of the trigeminal nerve.

The following case illustrates the application of the infratemporal fossa approach for tumours in the parasellar region.

Case 4: A 35-year-old man was seen in April 1977 with a 3 years' history of complete palsy of the oculo-motor nerve. Polytomography and a CT scan revealed the presence of a cystic parasellar tumour. In January 1977 the intracranial portion of the tumour was removed by the neurosurgeon. The histological diagnosis was 'chromophobe adenoma of the hypophysis'. In April 1977 the tumour was removed radically through a left infratemporal approach with subtotal petrosectomy. The mandibular condyle was resected, the zygoma and lateral orbital wall were temporarily reflected and the mandibular division of the facial nerve was temporarily sectioned. The entire temporalis muscle was mobilized from the temporal squama and reflected interiorly, leaving it attached to the muscular process of the mandible. The internal carotid artery was identified and exposed as far as the cavernous sinus after ligation of the middle meningeal artery and section of the third and second trigeminal divisions at the foramina ovale and rotundum. After removal of the pterygoid process the tumour, situated medial to the carotid artery, was removed. Bleeding from the cavernous sinus was stopped with oxycel packing. The operative cavity was filled with the entire temporalis muscle. The mandibular branch of the facial nerve was anastomozed using two 11:0 nylon sutures. Two negative suction catheters were introduced in the neck and temporal region and the wound closed in two layers. The patient made an uneventful recovery and was dismissed from hospital 10 days later.

Discussion and Conclusions

Table I shows the etiology of lesions requiring the infratemporal fossa approach in 51 patients. The most common tumours were: (a) glomus jugulare tumours which had produced complete destruction of the infralabyrinthine bone to the pyramid tip; (b) meningiomas involving the pyramid tip and sphenoid bone; (c) chordomas of the clivus; and (d) squamous cell and adenoid-cystic carcinomas originating from the nasopharynx or infratemporal fossa.

Thirteen patients (25 per cent) were referred following subtotal intracranial removal of the tumours by neurosurgeons.

The results obtained by using the three types of infratemporal fossa approaches described above are shown in Table II. Forty-two of the 51 tumours could be radically removed. The number of total extirpations was higher when the lesion was limited to the infralabyrinthine and apical regions of the temporal bone (95 per cent), less for lesions situated in the clivus (78 per cent), and particularly low for the parasellar area (50 per

TABLE I

INFRATEMPORAL FOSSA APPROACH TO LESIONS IN THE TEMPORAL BONE AND BASE OF THE SKULL

Diagnosis	Number of patients	Patients referred by neurosurgeon after previous partial resection
Glomus jugulare	14	2
Meningioma	7	3
Chordoma	7	4
Squamous cell carcinoma	6	
Adenoidcystic carcinoma	4	
Vagus neurinoma	4	1
Rhabdomyosarcoma	2	
Congenital cholesteatoma	2	
Ceruminoma	1	
Osteoblastoma	1	
Chondroma	2	2
Malignant chromophobe adenoma	1	1
Total	51	13 (25%)

TABLE II

RESULTS OF INFRATEMPORAL FOSSA APPROACH

Localization of tumour	Removal of tumour	
	Partial	Radical
A. Infralabyrinthine and apical region of temporal bone	1/22 (5%)	21/22 (95%)
B. Clivus and epipharynx	5/23 (22%)	18/23 (78%)
C. Parasellar region	3/6 (50%)	3/6 (50%)
Total	9/51 (18%)	42/51 (82%)

cent). These figures reflect the progressive difficulty encountered when extending the infratemporal fossa approach. Familiarity with the anatomy of the most hidden portions of the base of the skull has considerably improved the results in our most recent series of cases.

The price that had to be paid for the infratemporal fossa removal of tumours of the pyramid tip and skull base is seen in Table III. Thirty-four of 37 patients (92 per cent) presenting with an intact inner ear function had a post-operative total conductive hearing loss due to the obliteration of the middle-ear cleft following sacrifice of the Eustachian tube. Three out of 37 patients lost their inner ear function during tumour removal. The anterior transposition of the facial nerve has permitted the preservation of normal facial function in 31 out of 51 patients (61 per cent). In 13 instances (25 per cent), facial function was improved by reconstructing the continuity of the infiltrated facial nerve with a nerve graft. In 7 patients

TABLE III

FUNCTIONAL LOSS DUE TO INFRATEMPORAL FOSSA APPROACH (51 PATIENTS)

A. *Hearing loss*		
Conductive	34/37	92%
Total deafness	3/37	8%
B. *Facial movements*		
Normal	31/51	61%
Improved	13/51	25%
Impaired	7/51	14%
C. *Occlusion*		
Normal	20/51	39%
Impaired	31/51	61%
D. *Function of trigeminal nerve*		
Normal	25/51	49%
Impaired	26/51	51%

(14 per cent), temporary resection of one or of all three peripheral branches of the facial nerve induced a post-operative impairment of facial function. The mandibular condyle was preserved in 20 out of 51 patients (39 per cent). In 31 cases (61 per cent) the capitulum of the mandible and the glenoidal fossa of the temporo-mandibular joint were permanently eliminated, thus inducing a mild degree of malocclusion. None of these patients required special orthodontic measures in order to rehabilitate the masticatory function. In 26 instances a loss of sensitivity in the face was induced by section of the mandibular and/or the maxillary division of the trigeminal nerve.

In view of the multiple nerve deficiencies presented by the patients before surgery and of those which would have resulted from the further growth of the lesion, the above listed post-operative functional losses are justifiable. The number of unexpected post-operative complications was surprisingly low (Table IV). Three patients had a cerebrospinal fluid leakage through the surgical wound. In one instance the leak disappeared under conservative treatment within one week. In another patient a revision of the wound with transposition of a further portion of the temporalis muscle was necessary. In the third patient the neurosurgical attempt to reduce the cerebrospinal fluid by an atrioventricular drainage produced

TABLE IV

COMPLICATIONS OF INFRATEMPORAL FOSSA APPROACH (51 PATIENTS)

Complication	Number of patients	%
— CSF—leak	3/51	6
— Infection	2/51	4
— Death	1/51	2
Total	6/51	12

an intraventricular haemorrhage which led finally to death. This unique fatality occurred after the one-stage removal of a glomus jugulare tumour type D (i.e. with intracranial extension). The profuse cerebrospinal fluid leak was due to the large post-operative defect in the posterior cranial fossa dura. In view of this experience we have never since removed intracranial extensions of a base of skull tumour in one stage. As already mentioned we prefer in such instances to have a two-stage removal consisting in a neurosurgical operation followed by a neuro-otological intervention with an interval of 1-3 months.

Infection of the abdominal fat introduced to obliterate the temporal bone cavity occurred in two instances. In both cases primary wound closure had been attempted in spite of the presence of an infected open cavity prior to surgery. In both cases drainage of the wound under antibiotic treatment led to uneventful secondary healing. Nevertheless, a plea must be made (in order to avoid future partial tumour removals resulting in an infected open cavity) in favour of radical surgery with primary wound closure.

Only the long-term results will prove the definitive value of the infratemporal fossa approach for tumours of the skull base and pyramid tip. We feel, however, that already at this stage the lateral route presented has to be made known because it has permitted the safe total removal of lesions previously considered to be inaccessible. The infratemporal fossa approach also has several applications other than for tumour surgery. We have, for example, used the type A infratemporal fossa approach to remove successfully five aneurysms of the internal carotid artery situated at or in the carotid foramen. In view of the large exposure the continuity of the carotid artery was reconstructed without any loss of function by using a graft from the saphenous vein (Fisch, 1976; Schubiger, Fisch and Senning, 1978).

Summary

In spite of the development of a superior (middle cranial fossa) and posterior (translabyrinthine) approach to the temporal bone, tumours situated in the infralabyrinthine and apical compartments of the pyramid and surrounding base of the skull were still a challenge for neurosurgeons and otologists as well. The infratemporal fossa approach closes the existing gap in the surgical management of the most hidden lesions of the temporal bone. The approach features the permanent anterior transposition of the facial nerve, resection of the mandibular condyle and mobilization of the zygoma and lateral orbital rim. Obliteration of the pneumatic spaces of the temporal bone, with permanent occlusion of the Eustachian tube and blind sac closure of the external auditory canal, avoids the danger of post-operative infection and leads to primary wound healing in the shortest time. Three types of infratemporal fossa approach are presented and discussed on the basis of 51 operated patients.

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