Stereotactic Transcerebellar Approach to Pontine Lesions through the Middle Cerebellar Peduncle

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Summary

A stereotactic approach to the pons through the middle cerebellar peduncle based on MR studies was used to biopsy 18 patients. The stereotactic coordinates and angles were defined with reference to three orthogonal planes (mid-sagittal, IVth ventricular floor and pontomedullary junction).

The pathological diagnoses were in keeping with clinical outcome and comprised five high-grade astrocytomas, three low-grade astrocytomas, two glioblastomas multiformes, two oligodendrogliomas, two primitive neuroectodermic tumours, two lymphomas, one medulloblastoma, and one tuberculosis. This approach provides a high yield of positive histological diagnoses with little morbidity (transient neurological deficits in two cases) and thereby avoids inappropriate therapy.

Introduction

Despite improved brain stem imaging by means of magnetic resonance, intrinsic tumours of the brain stem must be verified histologically before therapy. When radiographic and clinical findings are strongly suggestive of a mass lesion located within a vital area of the brain stem, patients are often treated without the

benefit of a histologic diagnosis. This empiric approach carries a risk of inappropriate therapy. In a series of 26 patients with pontine mass lesions resembling tumours in presurgical investigations, Abernathy et al¹ noted three cases of demyelination, three infarcts and two cryptic AVMs.

Histologic confirmation has the added advantages of tumour grading, definition of the spatial configuration of gliomas, prognosis orientation and precise evaluation of new chemotherapeutic efficacy on specific histological subgroups (e.g. oligoastrocytomas and primitive neuroectodermic tumours). Mesencephalic lesions in the upper brain stem are usually biopsied via a transfrontal-transcoronal trajectory^{2,4,5}. In the lower brain stem, lesions of the pons and medulla are more difficult to reach, especially in children with a thin and horizontally inclined mesencephalon.

Stereotactic suboccipital transcerebellar biopsy^{1,7} through the middle cerebellar peduncle is a safe approach, even in children, to the pons and medulla which are often considered as inaccessible by current stereotactic biopsy techniques. Gonçalves-Ferreira³ studied the three dimensional arrangement of posterior fossa structures and their variations, based on comparative analysis of serial cuts of several specimens. He went on to propose a new stereotactic

Figure 1 Axial stereotactic MRI with different possible simple oblique trajectories through the middle cerebellar peduncle for this high grade glioma of the pons.

reference system for the posterior fossa comprising three orthogonal planes (midsagittal, IVth ventricular floor and pontomedullary junction). In a consecutive series of 18 stereotactic approaches to the pons, we quantified the trajectory and angle limits with reference to these new anatomical references defined on the basis of human autopsy material, to determine the safety and efficacy of those procedures based on MR imaging.

Patients and Methods

Eighteen patients (nine children, nine adults) with primary space-occupying lesions of the pons underwent MR (11 cases) or MR and CT (seven cases) scan-guided stereotactic surgery at Bicêtre Hospital from December 1991 to December 1996. These operations represented 7% of a total of 250 stereotactic biopsy procedures performed during this period. The patients' ages ranged from five to 68 years (mean: 25.3 years). The time between onset and diagnosis ranged from ten days to 11 months (mean four months). Preoperatively, all but one of the patients had ipsilateral cranial nerve deficits as well as ataxia, cerebellar and long tract signs.

Additional findings included nystagmus, headache, vomiting, and upper motor neuron signs. One patient had previously undergone sub-occipital craniectomy for high posterior fossa pressure with tonsillar ectopia. Two patients (nos. 7 and 10) had undergone unsuccessful stereotactic biopsy of the lesion in another institution and were referred to us for biopsy.

All patients had pre-operative high-resolution contrast-enhanced MRI at our institution. The Leksell G frame was used in each case. The frame was applied under local ($n = 9$) or general anaesthesia ($n = 9$). The frame was fixed with the patient's head flexed forwards by 25° to 30° between the orbitomeatal and horizontal planes. This placed the plane of the middle cerebellar peduncle parallel to the base of the frame and consequently allowed us to use a simple oblique trajectory. The target was located in a 1.5-T Siemens MR unit alone (11 cases) or together with a GE 8800 CT scanner (seven cases). The MR scans consisted of 1.5 mm contiguous axial and coronal slices with SPGR and gadolinium enhancement. The computer software (Surgical Planning System, Elekta) calculated the x, y, and z coordinates of the target together with the entry points and the value of

the two angles' frame α and β , and facilitated 3D reconstruction of the trajectory. With this software the target point can also be transposed to angiographic data to define an avascular trajectory. The trajectory (figure 1) was based on three orthogonal planes: the midsagittal plane, the IVth ventricular floor plane and the pontomedullary junction plane. Each trajectory was defined by the following two polar coordinates: the angular distances of its double obliquity relative to the midsagittal plane (horizontal angle) and to the pontomedullary junction plane (vertical angle). Once the x, y and z adjustments had been set on the stereotaxic frame in the operating suite, under general anaesthesia and in the prone position, the scalp was prepared over the calculated entry point. A burr hole was made through the skull, the dura matter was opened and the cortical surface was cauterized.

The biopsy cannula was advanced to the target point along a single probe trajectory and a 10 mm core biopsy was obtained. If smear preparations of this first biopsy were not diagnostic, further biopsies were obtained (mean=2). Immediate postoperative CT scans were used to assess the accuracy of target placement and to reveal possible complications.

Results

A positive pathological diagnosis was obtained in 18 cases. A second biopsy was necessary in one case (no. 14). This patient had been treated in another institution with radiation therapy and chemotherapy; there had been a transient response to treatment but a subsequent rapid deterioration. The first biopsy specimen consists of wholly necrotic material, and the second specimen yielded a diagnosis of glioblastoma. High-grade astrocytomas were found in five cases, glioblastoma multiforme (figure 2) in two cases, low-grade astrocytomas in three cases, oligodendrogliomas in two cases, primitive neuroectodermic tumours (PNET) in two children, a primary cerebral lymphoma type B in one case (no. 6) and type T in a patient with acquired immunodeficiency syndrome (no. 15), a medulloblastoma in an adult, and tuberculosis (no. 7) in one case. No permanent neurological deficits occurred after the procedure. Transient neurological deficits occurred in two cases, with facial paresis in one and diplopia in another.

Figure 2 Unusual aspect of a bifocal intrapontine glioblastoma in a child on sagittal MR study which could mimic abscesses of the brain stem.

In both cases neurological status returned to baseline after three weeks on steroids. An early haemorrhagic complication with no clinical deficit was noted on immediate post-operative CT after the second biopsy in the child previously treated with radiation therapy and chemotherapy in another institution. The small haemorrhagic area was located within the tumour (glioblastoma multiforme) and resolved within two weeks. Liquefied necrosis of a large high-grade cystic astrocytoma was aspirated at the time of the biopsy and this resulted in an immediate neurological improvement (no. 8).

A catheter was then implanted stereotactically a few weeks later using the transcerebellar approach and was connected to a Rickham reservoir. The patient improved and only a small number of percutaneous aspirations were necessary. Three patients had preoperative ventriculoperitoneal shunting and one patient required immediate postoperative ventricular shunting. Outcome was in keeping with the histological grade of the tumours. The three patients with benign astrocytomas are alive 50, 28 and 36 months after diagnosis, with a slow

Figure 3 Tuberculosis of the pons.

clinical deterioration in two cases and anatomical evidence of tumour progression in one. The mean survival time of the seven patients with malignant gliomas was 11 months; the only surviving patient with a high-grade glioma (no. 12) has clinical and anatomical evidence of tumour progression.

The two children with PNET located in the pons died shortly after the biopsy: patient no. 13 had arrived from North Africa with a large lesion surrounded by marked oedema; he deteriorated before treatment requiring tracheostomy, and died during radiation therapy. The second child (no. 16) had tetraplegia with a lower cranial nerve deficit and no response to chemotherapy.

The adults with medulloblastoma (no. 17) and the primary type B (HIV-negative) cerebral lymphoma (no. 6) are free of recurrences 42 and 36 months after biopsy respectively. The HIV-infected patient with type T cerebral lymphoma (no. 15) treated with radiation therapy alone survived for nine months after the histological diagnosis. The patient (no. 11) with a grade 1 oligodendroglioma revealed by an acute, transient neurologic deficit due to a small spontaneous haemorrhage within the lesion received no treatment. The lesion remains stable 38 months after diagnosis, and the patient is free of neurological deficits. The patient (no. 7) treated for a tuberculosis (figure 3) is well and alive ten months after diagnosis.

In all cases the biopsy trajectory was quantified using the new anatomical reference system proposed by Gonçalves-Ferreira³. The mean horizontal angle (figure 4) was 32° (10° to 60°). A simple oblique trajectory was used in 14 cases, with the head inclined forwards (25° to 30°) in the frame. The linear distance at which the trajectory intercepted the ventricular floor relative to the midline was never less than 1 cm. The trajectory never passed through the ventricular structures or the subarachnoid space between the cerebellum and medulla. The mean vertical angle was 27° (20° to 40°) (figure 5).

Discussion

The suboccipital transcerebellar route via the middle cerebellar peduncle provides the safest and most direct trajectory to the lower anterior median and lateral parts of the pons and the upper part of the medulla. We based our anatomical study on the three orthogonal reference planes proposed by A. Gonçalves-Ferreira³, which are the midsagittal plane, the IVth ventricular floor plane and the pontomedullary junction plane.

These safe intraparenchymal trajectories avoid the transverse sinus, passing through the lower border of the brachium pontis (middle cerebellar peduncle) which also passed through the pontomedullary junction. If the patient's head is sufficiently inclined in the Leksell frame (mean angle 25° to 30°), the trajectory is included in a single axial MR plane parallel to the stereotactic base frame and becomes a simple obliquity, the angle value of which is defined with regard to the fastigium and the dentate nucleus, the lateral part of the IV ventricle.

The upper, lower and lateral limits of the dentate nucleus, the upper limit of the brachium pontis and the position of the obex are defined with reference to the three planes in the work by Gonçalves-Ferreira³. We prefer to stay at least 1 cm from the midline on the plane of the floor of the IVth ventricle to avoid the dentate nucleus posteriorly and cranial nerve nuclei anteriorly among the floor of the ventricle, which is often displaced. Most pontine lesions project to one side or other, and this characteristic guides the planning of the trajectory. In two cases we obtained biopsies from midline lesions by approaching from the side of the most significant neurological symptoms. The

Figure 4 Stereotactic suboccipital approach to the pons via the middle cerebellar peduncle: horizontal angles (relative to the midsagittal plane) reconstruction. 14 approaches were in between trajectory no. 1 and no. 2. Two approaches were performed between trajectory no. 3 and two between trajectory no. 4.

Figure 5 Stereotactic suboccipital approach to the pons via the middle cerebellar peduncle: vertical angles (relative to the pontomedullary junction plane) reconstruction. All approaches were performed in between trajectories a and b. The head is anteriorly flexed so that the base of the frame is at the level of C2 and the biopsy is in a plane parallel to the stereotactic frame's base.

simple oblique trajectory with the head inclined forwards allows an entry point and a target point to be defined in the same MRI plan, far below the lateral sinus, and does not necessitate reconstruction of the trajectory.

The diagnostic yield obtained with small pieces of tissue is a matter of concern. In two cases the first biopsy procedure was performed in another institution and no histological diagnosis was obtained, as the histological aspect corresponded to that of normal brain stem tissue.

We performed another stereotactic procedure with both MRI and CT pre-operative studies, and reached the target point with no problem. In one case the first horizontal trajectory angle was 50° from the anatomical midline. The pre-operative stereotactic anatomical study is usually performed in the supine position on the CT or MR table and the patient is then at the time of biopsy in the prone position.

The whole brain between these two extremes can move within the skull and the frame, and

Table 1 Profile of 18 patients with pontine mass lesions diagnosed by suboccipital transcerebellar stereotaxic biopsy

Case No	Age (yrs) & sex	Pathology	Postop treatment	Follow-up duration	Follow-up status
1	14 / M	grade 2 astro	VPS+Rt	50 mos	deteriorating
2	14 / M	glioblastoma	Rt+Ct	14 mos	died
3	12 / F	grade 2 astro	Rt+Ct	28 mos	deteriorating
4	20 / M	grade 3 astro	Rt+Ct	14 mos	died
5	7 / F	grade 4 astro	Rt+Ct+VPS	14 mos	died
6	54 / M	lymphoma	Ct+Rt	36 mos	alive & well
7	68 / M	tuberculosis	Mt	10 mos	alive & well
8	6 / F	grade 4 astro	Rt+Ct+Cd+VPS	12 mos	died
9	25 / F	grade 3 astro	VPS+Rt	9 mos	died
10	40 / M	grade 2 astro	Rt	36 mos	alive & well
11	21 / M	grade 1 oligo	—	38 mos	alive & well
12	9 / F	grade 4 astro	Rt	11 mos	deteriorating
13	10 / M	PNET	Rt	1 mos	died
14	8 / M	glioblastoma	Ct+Rt	9 mos	died
15	39 / M	lymphoma	Rt	9 mos	died
16	5 / M	PNET	Ct	2 mos	died
17	68 / M	medulloblastoma	Rt	42 mos	alive & well
18	37 / M	grade 2 oligo	Rt	50 mos	alive & well

astro = astrocytoma; oligo = oligodendroglioma; PNET = primitive neuroectodermic tumour; Rt = radiation therapy; Ct = chemotherapy; Mt = medical treatment; VPS = ventriculoperitoneal shunting; Cd = cyst drainage; mos = months.

when the angle from the midline is too large, the target can be displaced forwards between these two positions. This is why the second trajectory was more parallel to the midline in these two cases (15° relative to the anatomical midline).

In one of these initially unsuccessful procedures the posterior plot of the frame was removed to facilitate the approach once the patient was in the prone position in the operating room, and this could have modified the anatomical landmarks within the stereotactic space. Post biopsy CT or MRI was always done, and confirmed the site of the biopsies.

Another controversial point is the type of anaesthesia. We recommend general anaesthe-

sia for both adults and children. In two cases transient bradycardia occurred during surgery as the probe entered the brain stem.

A risk of per-operative facial neuralgia has been described if the trigeminal nucleus is involved, and this could interrupt a procedure under local anaesthesia. Unipolar neurostimulation^{6,8} of the target has been proposed in conscious patients, the biopsy only being done when no motor or sensory phenomenon is observed⁴.

The location of the lesion dictates the biopsy approach. In the case of brain stem mass lesions located near the midline, at or above the pontomesencephalic junction, the ipsilateral trans-frontal approach is used. The suboccipital tran-

scerebellar approach is used for lesions of the caudal pons, especially when the lesion is lateral or laterally involves the cerebellar peduncle (a fairly frequent situation) or when the lesion is anterior in the pons, or in children with a thin mesencephalon, in which case the transfrontal approach to the caudal part of the brain stem could be dangerous. We did not use the transtentorial route, which carries a risk of bleeding at the pial surfaces of the cerebellum and mesencephalon. With the Leksell stereotactic device this transcerebellar approach is simple in the prone or lateral position.

Some groups consider that histological studies of pontine lesions are not necessary and that treatment can be based on the natural history of the lesion and the MRI findings. Even though high-resolution MRI provides excellent sensitivity and topographic relation, definitive diagnosis and specific therapy require accurate pathologic definition. Diagnostic errors and complications of empiric therapy are well documented^{1,4}.

The prognosis of patients with brain stem tumours appears to depend on the tumour grade and, in the case of gliomas, on the presence of an oligodendroglial component. In our series the histological diagnosis was unexpected or modified treatment in nine cases (50%): two PNET, one medulloblastoma in an adult (with a good response to radiation therapy), two lymphomas, one glioblastoma multiforme with two locations within the pons, one tuberculosis, and one grade 1 oligodendroglioma revealed by a transient haemorrhagic neurological deficit for which no treatment was proposed (the patient was deficit-free and showed no tumour progression with a follow-up of 38 months).

Another patient (no. 10) had been treated nine years previously for a supratentorial or infratentorial low-grade astrocytoma, and had received post-operative radiation therapy, including the brain stem. As additional irradiation carried a risk of necrosis, histological verification was essential; in the event the lesion was a low-grade astrocytoma. Non neoplastic lesions in this region such as cryptic angiographically occult, thrombosed arteriovenous malformations, demyelinating disease, abscesses and infarcts, are readily identified on MR.

During the same period (1991-1996), 20 other patients with lesions located within the pons, with clinical or radiological evidence of benignity

were managed in our institution without a histological diagnosis. It is noteworthy that a case of possible demyelination was found at autopsy to be a lymphoma while a possible infarct was in fact a glioma. Most modern therapeutic protocols for tumoral lesions cannot reach a valid conclusion if a histological diagnosis is not required. Stereotaxic biopsy can provide accurate histological specimens with a low complication rate (even in this location) and a good correlation with clinical outcome.

This procedure should be considered for all patients entering clinical trials. The transcerebellar route to the pons via the middle cerebellar peduncle is facilitated by the anatomical coincidence between the lower limit of the middle cerebellar peduncle and the pontomedullary junction. The horizontalization of the brachium pontis when the head is flexed forwards provides a simple oblique trajectory and safe access to the pons, with reference to the midline and floor of the IVth ventricle with the angles as defined above.

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