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# Image Directed Stereotactic Surgery for Brain Stem Lesions*

**G. P. Kratimenos[1], R. M. Nouby[1], R. Bradford[2], M. F. Pell[1], and D. G. T. Thomas[1]**

[1] Gough Cooper Department of Neurological Surgery, National Hospital for Neurology and Neurosurgery, London, and [2] Royal Free Hospital, London, U.K.

## Summary

Advances in neurological imaging may have increased the diagnostic accuracy and the detection rate of intrinsic brain stem lesions, but a histological diagnosis is still an essential requirement for rational and appropriate management. Open exploration allows biopsy and resection in cases where an exophytic component is present. The surgical inaccessibility and the resultant morbidity of these approaches, however, associated with a low diagnostic yield in cases with no visible surface abnormality, are important limiting factors.

A series of 45 brain stem lesions stereotactically approached with CT or MRI guidance is presented. A transcortical frontal pre-coronal trajectory was used in all of them. Haematoma was preoperatively diagnosed in 10 cases and the procedure was for therapeutic aspiration. Of 35 cases where the diagnosis was uncertain, although intrinsic tumour was suspected, positive results were obtained in 33, while unexpected findings of granuloma, lymphoma, angioma, leucoencephalopathy, vasculitis and radiation necrosis were found in over 10% of the cases. There were no operative deaths and the morbidity was low. In no case was there a permanent neurological deterioration directly related to the procedure, although there was a transient deterioration in two patients and one patient required early reaspiration of a haematoma.

Image directed stereotactic approaches to brain stem lesions can combine a high degree of accuracy (offering positive histological diagnoses) with a low operative morbidity. MRI directed biopsies can complement CT guided ones thus increasing the number of suitable cases and improving the success rate. The frontal precoronal transcortical trajectory provides safe access to the majority of the brain stem targets.

*Keywords:* Brain stem; biopsy; neoplasia; computed tomography, stereotactic surgery.

## Introduction

Despite advances in neuroimaging which undoubtedly have increased the diagnostic accuracy and the detection rate of small intrinsic brain stem lesions, the management of these lesions remains challenging.

Reluctance in the past to perform open biopsies because of the surgical inaccessibility and the significant morbidity following exploration of the area[29], has been recently replaced with a more optimistic tendency of aggressive surgical resection when a distinct plane separates pathological from normal anatomy[15, 16, 23, 46]. When an exophytic component of the lesion is present, open biopsy or even resection can be accomplished effectively and with acceptable morbidity. For the majority of the intrinsic lesions of the brain stem, however, an open biopsy will be associated with a low success rate and an exploration of the area with prohibiting morbidity and mortality[1, 24].

Histological diagnosis is essential for the instigation of rational and appropriate treatment, in view of the fact that a significant number of these lesions are preoperatively misdiagnosed, requiring treatment other than radiotherapy.

Stereotactic biopsy techniques under CT or MRI direction have been shown to be safe, reliable and effective for supratentorial lesions[2, 3, 5, 6, 10, 30, 31, 33, 37, 41–44]. Their application in the management of lesions of the brain stem has been relatively limited, despite the successful attempts of Backlund since 1975[32]. However, an image directed stereotactic approach to the brain stem potentially can provide not only high diagnostic accuracy combined with low morbidity, but also an effective and safe method of therapeutic intervention.

We present our experience of CT and MRI directed biopsies of 45 intrinsic brain stem lesions.

## Materials and Methods

Forty five patients with mass lesions of the brain stem underwent CT or MRI directed stereotactic surgery at the National Hospitals for Neurology and Neurosurgery (Table 1). The patients' ages varied

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Table 1. *Clinical Details of Patients*

| No | Sex | Age | Site | Duration | Image | Pathology | Result |
|---|---|---|---|---|---|---|---|
| 1 | M | 49 | midbrain | 6 weeks | CT | metastatic Ca | DXRT, 2 months later |
| 2 | F | 4 | midbrain-pons | 2 months | CT | astrocytoma I-II | DRXT, improved |
| 3 | M | 12 | pons | 3 months | CT | malignant glioma | DXRT, died 8 months later |
| 4 | F | 23 | medulla | 3 months | CT | haematoma, no AVM | excellent |
| 5 | M | 19 | pons-medulla | 4 months | CT | astrocytoma II | DXRT, alive 3 years later |
| 6 | M | 18 | midbrain | 4 months | CT | astrocytoma III | DXRT, died 6 months later |
| 7 | M | 30 | pons | 3 weeks | CT | haematoma, no AVM | good, slight ataxia remains |
| 8 | F | 24 | pons-medulla | 8 months | MR | astrocytoma I | DXRT, alive 6 years later |
| 9 | F | 20 | medulla | 6 weeks | CT | haematoma, no AVM | good, mild IX and X paresis |
| 10 | F | 35 | midbrain | 2 weeks | CT | haematoma, no AMV | excellent |
| 11 | M | 59 | pons | 4 months | MR | astrocytoma II | DRXT, died 22 months later |
| 12 | M | 46 | midbrain-pons | 18 months | CT | astrocytoma II | DRXT, died 14 months later |
| 13 | M | 40 | midbrain-pons | 4 weeks | CT | astrocytoma III | DRXT, died 2 months later |
| 14 | F | 35 | pons | 6 weeks | CT | haematoma, no AVM | fair-reaspiration-improved |
| 15 | F | 29 | pons-medulla | 3 months | MR | inconclusive | unchanged |
| 16 | M | 38 | pons-medulla | 1 week | CT | astrocytoma II | DXRT, improved, no follow-up |
| 17 | F | 19 | midbrain-pons | 2 months | CT | astrocytoma II | DXRT, improved, alive 3 years |
| 18 | M | 18 | pons-medulla | 4 weeks | CT | astrocytoma IV | DXRT, died 4 months later |
| 19 | F | 5 | midbrain-pons | 4 weeks | CT | astrocytoma IV | DXRT, no follow-up. |
| 20 | F | 51 | midbrain | 6 weeks | CT | metastatic Ca | DXRT, died 3 months later |
| 21 | M | 13 | midbrain | 8 weeks | CT | haematoma, no AVM | excellent |
| 22 | M | 23 | pons-medulla | 5 months | CT | astrocytoma II | DXRT, alive 2 years later |
| 23 | F | 29 | midbrain | 12 months | CT | astrocytoma II | DXRT, chemotherapy, died |
| 24 | M | 44 | pons | 4 weeks | CT | haematoma, ?angioma | moderate |
| 25 | M | 40 | pons | 24 months | MR | astrocytoma I | unchanged, alive 3 yeas later |
| 26 | M | 2 | midbrain | 6 months | CT | astrocytoma III | no follow-up |
| 27 | M | 11 | midbrain | 4 weeks | CT | astrocytoma I-II | DXRT, alive 3 years later |
| 28 | F | 42 | pons | 6 months | CT | radiation necrosis | improved with steroids |
| 29 | F | 4 | pons-medulla | 6 weeks | CT | neuroblastoma | DXRT, chemotherapy, died |
| 30 | M | 43 | midbrain-pons | 8 weeks | CT | haematoma, AVM | good, rebled 2 years later |
| 31 | M | 45 | midbrain-pons | 4 weeks | CT | haematoma | good |
| 32 | F | 35 | midbrain | 6 months | CT | haematoma, no AVM | good, no further treatment |
| 33 | M | 33 | pons | 1 week | CT | haematoma, no AVM | excellent |
| 34 | F | 6 | midbrain | 4 weeks | CT | astrocytoma II | DXRT, alive 18 months later |
| 35 | M | 3 | midbrain | 8 weeks | CT | astrocytoma II | DXRT, alive 12 months later |
| 36 | M | 45 | pons | 4 months | MR | lymphoma | DXRT, excellent result |
| 37 | M | 6 | midbrain-pons | 2 months | CT | astrocytoma III | DXRT, died 8 months later |
| 38 | F | 5 | pons | 6 weeks | CT | astrocytoma II | DXRT, alive 10 months later |
| 39 | M | 10 | pons | 4 weeks | CT | astrocytoma II | DXRT, alive 10 months later |
| 40 | F | 35 | midbrain | 8 weeks | MR | granuloma | antibiotics, excellent |
| 41 | M | 6 | midbrain | 4 weeks | CT | astrocytoma II | DXRT, alive 6 months later |
| 42 | M | 21 | medulla | 4 months | CT | vasculitis | stereoids, excellent |
| 43 | M | 32 | pons | 2 months | MR | leucoencephalopathy | moderate |
| 44 | F | 38 | pons-medulla | 4 months | CT | inconclusive | good ?, granuloma |
| 45 | M | 60 | pons-medulla | 6 weeks | CT | metastatic adeno Ca | DXRT, died 2 months later |

between 2 and 60 years. Eighteen patients were female and twenty-seven were male. The preoperative symptomatic period extended from 1 week to 2 years. All patients underwent preoperative cerebral angiography, high resolution contrast enhanced-CT and preoperative MRI. Thirteen lesions were located in the mesencephalon, twelve in the pons, and three in the medulla, while eight lesions occupied the mesencephalic-pontine junction and nine the ponto-medullary junction. A Brown-Roberts-Wells (BRW) or a Cosman-Roberts-Wells (CRW) CT-directed stereotactic system was used for biopsies under CT guidance (Trent Wells Inc., Southgate California and Radionics, Burlington, Massachusetts)[6]. For MRI-directed biopsies a prototype modification of the BRW frame developed by Trent Wells was employed. The elimination of ferromagnetic components and other frame modifications necessary for MRI compatibility have previously been reported[5, 43]. Two or three targets within the lesion were chosen and target coordinates calculated using the CT or MR

scan software and the BRW/CRW software on an Epson HX-20 computer (Epson, West Placentia, California).

Surgery was performed under general anaesthesia. A transcortical frontal precoronal trajectory to the brain stem targets was used in all cases. The flexibility of the BRW or CRW system allows precise placement of the entry point parasagittally on or just in front the coronal suture ipsilaterally or contralaterally to the selected targets. The biopsy needle trajectory is entirely transparenchymal and avoids the posterior clinoid processes and free edge of the tentorium. Sagittal CT reformated images and sagittal MR images were particularly helpful in plotting a trajectory parallel to and through the brain stem axis. Biopsies were taken with a Sedan type side cutting needle which produces a core of tissue of approximately 5 × 1 mm. Histological examination was performed by immediate smear and paraffin sections.

## Results

Adequate specimens for histological diagnosis were obtained in 44 out of 45 patients. Therapeutic intervention (haematoma aspiration) was possible in 11 patients. In twenty-eight patients the lesion proved to be neoplastic (16 low grade gliomas, 7 high grade gliomas, 3 metastatic carcinomas, 1 lymphoma and 1 neuroblastoma), while in 4 cases, non-neoplastic conditions were diagnosed (Table 2).

Very unexpected histological diagnoses were made in 9 patients and in 6 of them the correct diagnosis changed treatment and/or prognosis (cases of lymphoma, angioma, granuloma, vasulitis and radiation necrosis). No increased neurological deficit resulted in any patient following the procedure, although transient deterioration, which resolved in 24 hours, was noted in two patients. One patient, required early reaspiration of a haematoma. Nine patients, who underwent aspiration of haematoma, showed objective neurological improvement during the early postoperative period and their subsequent follow-up (ranging from 18 months to 4 years) confirmed an excellent or good result. No patient without tumour seen at biopsy has progressed clinically in such a way as to suggest an incorrect diagnosis.

Table 2. *Results*

| | | | |
|---|---|---|---|
| total cases | 45 | positive biopsies | 43 |
| operative mortality | 0 | inconclusive results | 2 |
| tumours | 28 | haematomas | 11 |
| low grade gliomas | 16 | other | 4 |
| high grade gliomas | 7 | radionecrosis | 1 |
| Metastatic Ca | 3 | granuloma | 1 |
| Neuroblastoma | 1 | leucoencephalopathy | 1 |
| Lymphoma | 1 | vasculitis | 1 |

The 4 patients with lymphoma, vasculitis, radiation necrosis and granuloma made an impressive recovery following appropriate treatment and their clinical improvement has been maintained since.

Of the two cases with inconclusive histological diagnosis, one has remained unchanged for 36 months, while the other has considerably improved over a period of 4 months and the patient has been well for 2 years now (clinical evidence of the non-neoplastic nature of their pathology).

## Case Reports

*Case 1*

A 53 year old woman (Table 1, case 10), presented with a 2-week history of progressive right hemianaesthesia and hemiparesis, an internuclear ophthalmoplegia and absent right-sided gag reflex. A CT scan demonstrated a non-enhancing hyperdense space occupying lesion in the left mesencephalon. An MRI scan performed subsequently, showed the lesion to have a short $T_2$, consistent with a haematoma.

She underwent CT-directed stereotactic aspiration of a 5 ml haematoma, following which she made complete neurological recovery. A follow-up CT scan 1 month later demonstrated resolution of the lesion.

*Case 2*

A 59 year old man (Table 1, case 11) presented with a 4 month history of dizziness and ataxia. On examination he was found to have right cerebellar signs and right VIII$^{th}$ nerve function impairment. A CT scan performed at this time was reported as normal. He deteriorated rapidly during the following days developing an internuclear ophthalmoplegia, difficulty in swallowing and a right hemiparesis. An MRI scan demonstrated a deep right pontine lesion.

The lesion was biopsied with MRI-directed stereotactic technique and the histology was consistent with an astrocytoma. He made a satisfactory postoperative recovery, but despite both radiotherapy followed by chemotherapy he deteriorated and died 12 months later.

*Case 3*

A 35 year old woman (Table 1, case 14) complained of 6 weeks duration of left sided weakness involving upper and lower limbs, left sided deafness and ptosis and diplopia to the left. She had an ataxic gait and her gag reflex was absent. A CT scan showed a larger pontine enhancing lesion with an appearance consistent with a haematoma. An angiogram showed no pathologic blood circulation.

A CT-directed aspiration was performed and a 10 ml clot was evacuated. There was a marked postoperative improvement. A CT scan performed confirmed the successful aspiration, but 4 days later she developed a sudden onset of diplopia and left hemiparesis. Repeat CT scan showed a new haematoma, which was again aspirated and 3 ml of blood clot removed. The patient made an excellent recovery and has been well since.

*Case 4*

A 42 year old woman (Table 1, case 28), with a past history of squamous cell carcinoma of her face, for which she had refused

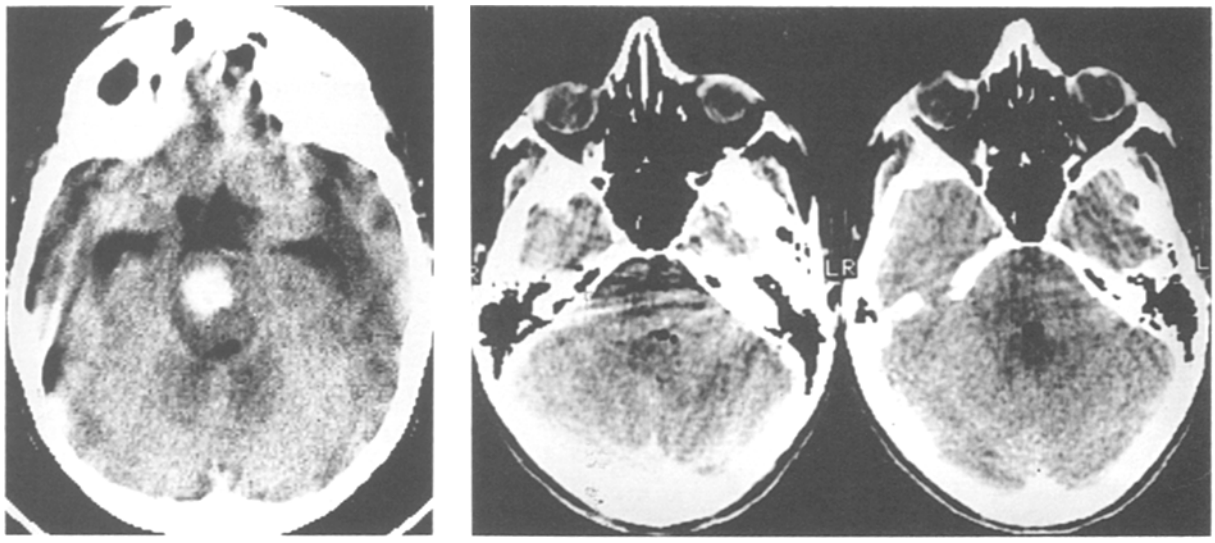


Fig. 1. Pre-operative (a) and post-operative (b) CT scans of the same patient (case 1). Stereotactic aspiration of the haematoma resulted in complete neurological recovery. The post-operative scan shows some air in the cavity but no residual haematoma

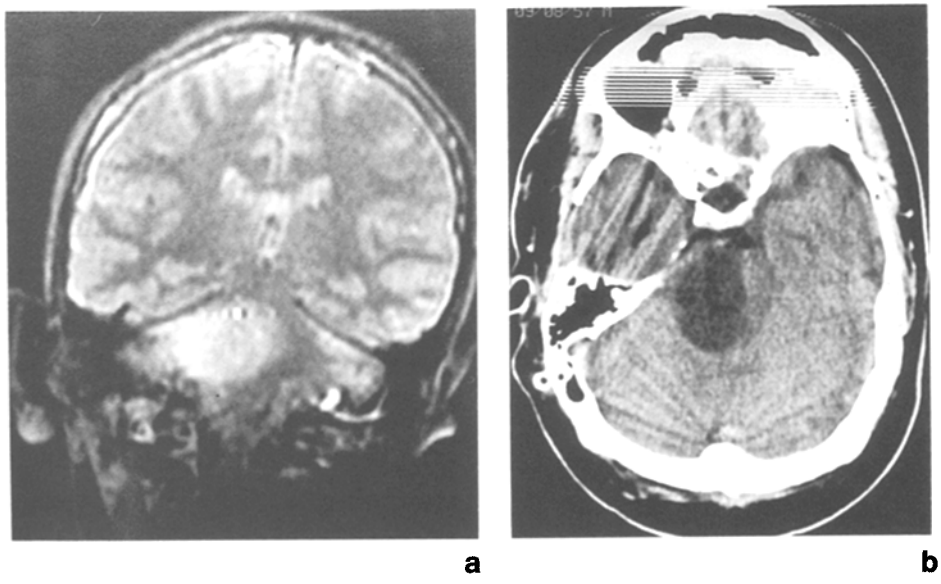


Fig. 2. Two of the nine unexpected histological diagnoses. The pre-operative MRI scan of the patient in case 5 in (a), while (b) shows the pre-operative CT scan of the patient in case 4. Although the radiographic pre-operative diagnosis in both cases was one of a neoplasm (possibly a glioma), the histological diagnosis revealed radionecrosis in (b) and lymphoma in (a)

surgery and was treated with radiotherapy, developed a progressive right sided hemiparesis over a period of 6 months. There was also a more recent right VII and VIII nerve function impairment. A CT scan showed a right pontine lesion, irregular and not enhancing. The preoperative diagnosis was one of an intrinsic tumour. An angiogram failed to show pathological tumour circulation.

A CT-directed biopsy of the lesion was performed and histological examination of the specimens showed foci of necrosis with hyaline and fibrinoid deposits on the blood vessel walls, consistent with the diagnosis of radionecrosis. She improved considerably with steroids and she lives an independent life 3 years later.

*Case 5*

A 45 year old man (Table 1, case 36), presented with a 4 month history of progressive ataxia, bilateral hemianaesthesia and VII nerve paresis. A CT scan performed failed to show any abnormality. Following further deterioration with the addition of right hemiparesis

and internuclear ophthalmoplegia, an MRI scan was performed and a right sided pontine lesion became visible.

The lesion was biopsied with MRI-directed stereotactic technique and the histological diagnosis was one of a low grade B cell Lymphoma. The post operative recovery was good and the final result following radiotherapy excellent. The patient is alive and well 2 years later with only a minor ataxic gait.

## Discussion

The surgical inaccessibility and the high morbidity which followed open operative attempts for biopsy or resection of intrinsic brain stem lesions had resulted in some reluctance to advocate any diagnostic or therapeutic operative treatment of these lesions[29]. Reports from the neurosurgical literature have chronicled the successful or not operative treatment of a variety of intrinsic brain stem lesions[4, 11, 12, 14–16, 18, 28, 36, 38–40, 45, 46]. Neurosurgical approaches for the biopsy or decompression of mass lesions of the brain stem have included the subtemporal[28], retromastoid[36], supracerebellar[47] and suboccipital routes, through the floor of the 4th ventricle[28, 38]. These approaches represent major surgical procedures and although some of the attempts were associated with low morbidity and mortality there is always the risk of failure to obtain diagnostic material[28], particularly if a clearly exophytic or surface lesion was not visualised[8, 9]. Brain stem lesions, therefore, were not uncommonly diagnosed and treated solely on clinical and radiographic grounds[20, 40] and it has even been argued that obtaining tissue is not warranted in some of these cases[13–15]. The broad spectrum of potential pathologic possibilities in this area, however, demands a firm histological confirmation of the exact nature of the pathology so that treatment options can be appropriate in the individual case. Lack of this diagnostic information can result in the instigation of empirical therapy, as the case was in the past, when the total population with brain stem lesions were treated with external beam irradiation and/or chemotherapy as a homogeneous pathological group[1, 20, 22, 35].

Imaging of the posterior fossa has improved considerably with MRI, since the computational artefacts due to compact bone seen with CT are absent. This high degree of sensitivity provides adequate information on the topographic relations of lesions within the brain stem, offering excellent localisation. Initial experience with MRI indicated that its superior resolution could often determine the exact nature of the pathological lesions[7, 23]. This assumption led to the recent development of an aggressive attitude to the management of brain stem lesions (especially those of a more benign nature), advocating open exploration and excision based on a preoperative diagnosis mainly reached with the help of MRI. The results have been variable, encouraging in some cases[17, 23, 26, 27], but discouraging in others[12, 18, 39, 48]. The impact of this improved sensitivity offered by the MRI, is shown in the present series by the 6 cases (13.33%) where an MRI directed biopsy was essential due to the inability of the CT images to demonstrate the lesions.

Despite the advances of the modern neuro-imaging techniques, a considerable number of brain stem masses, ranging from 10–20%, are preoperatively misdiagnosed[1, 8, 9, 19, 21].

In the present series, 9 of the 45 confident preoperative diagnoses based on CT and MRI appearances, were proved wrong at operation (20%), and in 6 of them (13.33%), this finding significantly changed the subsequent management and the prognosis.

Stereotactic intervention for diagnosis and treatment of the intrinsic lesions of the brain stem has been proved to be a reliable, safe and accurate method[1, 3, 5, 8, 9, 22, 24, 25, 31, 32, 34, 37, 41–44].

Trajectories which have been used include the right frontal through the intracranial neuraxis[8, 9, 24, 25], the transtentorial through the posterior cerebral hemisphere[2] and the infratentorial[32].

The inherent theoretical risks of the transtentorial route[2, 3] are that it crosses several pial planes and penetrates the tentorium, with a risk of haemorrhage. The transcerebellar approach, mainly advocated for the lateral pons or cerebellar peduncle, was used with satisfactory results in the 29 patients operated on by Backlund and his group over a period of 12 years[32] using the Leksell frame, in the 3 cases of Coffey and Lunsford also with the Leksell frame[8, 9], the 26 cases of Abernathey *et al.*[1] with the Kelly-Goerss modification of the Todd-Wells system and the 14 cases of Lobato and Rivas[31].

Although the transfrontal route traverses a longer route in the brain as well as the lateral ventricle, it carefully avoids the interpeduncular cistern[9]. We performed our brain stem biopsies through a transcortical frontal approach. Placement of the burr hole parasagitally on or in front or just behind the coronal suture, ipsilaterally or contralaterally to the selected target, creates a trajectory which is entirely transparenchymal avoiding the posterior clinoid processes and the free edge of the tentorium. A route to all divisions of the brain stem is thus permitted while avoiding the risk of

haemorrhage from the pial surface of the cerebellum or mesencephalon. This trajectory allows tissue sampling of varying depths along the brain stem axis, an advantage, since most neoplastic lesions are not confined to one division but are diffuse along the brain stem axis.

A stereotactic approach to brain stem lesions can provide a high yield of positive histological diagnosis with a low incidence of morbidity. Various authors[8, 9, 24, 25, 37] have emphasised that, with stereotactic control, the transfrontal approach to deep brain lesions is feasible and have further stressed the low morbidity associated with this technique. This is confirmed by our series where there were only two instances of transient and rapidly reversible clinical deterioration. The case of the early rebleed of the haematoma could be related more to the natural history of the pontine cryptic angioma rather than the safety of the technique.

As well as the benefits of accurate diagnosis achieved with stereotactic exploration of the brain stem it has also been possible in 10 cases (22%) to intervene therapeutically by aspirating brain stem haematomas. In these cases stereotactic surgery offers good operative resuls with a minimum of morbidity.

Since CT or MRI-directed biopsy of brain stem lesions is potentially the safest and most reliable method for the diagnosis of lesions within the brain stem, this procedure should be considered for all patients harbouring a brain stem lesion, particularly those entering any controlled therapy studies.

## Conclusions

A stereotactic approach to brain stem lesions potentially can provide a high yield of positive histological diagnosis with a low incidence of morbidity. As well as achieving a high diagnostic rate, therapeutic intervention in cases such as brain stem haematoma is also possible. The diagnostic error of the current imaging methods can be as high as 10–20%, and the correct histological diagnosis can make a difference in the management and final prognosis of up to 12% of the patients. Stereotactic biopsy should therefore be considered in all patients with brain stem lesions revealed by CT or MRI, prior to the instigation of any form of treatment, operative or not.

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Correspondence and Reprints: David G. T. Thomas, MA FRCP(G), FRCS(Ed), The National Hospital for Neurology and Neurosurgery, Queen Square, London WC1N 3BG, United Kingdom.