How safe is computed tomography-guided stereotaxy in neurosurgery and how should we select patients?

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With the advent of the Brown-Roberts-Wells stereotactic frame at the Queen Elizabeth Hospital in 1987, an evaluation was made of criteria for the safety and selection of patients for CT-guided stereotaxy. Sixty-five stereotactic procedures were performed on 47 men and 18 women from October 1987 to December 1994, which included biopsy, drainage of abscesses, and craniotomies. Fifty-five patients were operated on under local anaesthesia and 10 received general anaesthesia. Pathology was established by frozen section at the time of operation in 64 cases (98.4%), with the exception of one lesion in the pons. Bleeding was the single cause of the 4.7% mortality encountered, all of which occured in the initial few procedures. A radio-opaque ventricular catheter threaded through the stereotactically-guided cannula was found to be useful for draining abscesses and irrigation. The careful planning and selection of patients is very important, especially when the lesions are located in the pons or hypothalamus.

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Introduction

Obtaining a biopsy from a small and deep-seated intracerebral lesion by the conventional technique of the blind man's cane used in the 1950s would be considered hazardous in the present era. The introduction of stereotactic principles in the 1970s revolutionised these procedures through computed tomography (CT)-guided stereotaxy in neurosurgery.

The concept of advancing a probe to an unseen target under CT-guided stereotaxy has allowed removal of the diseased tissue with preservation of the healthy tissue. Although Horsley and Clarke were the first to put stereotactic principles into practice in laboratory experiments, it was not until 1947 when Spiegel et al introduced the concept of locating brain targets with respect to the ventricular system outlined by contrast medium.[1] The Brown-Robert-Wells (BRW) stereotactic system was designed to satisfy three goals. Firstly, to simplify transformation of the two-dimensional co-ordinates of a CT scan image into a three-dimensional point in real space. This localised point is defined by a vertical (VERT) co-ordinate in addition to the scan's anteroposterior (AP) and lateral (LAT) co-ordinates. Secondly, to provide an infinite number from which the three-dimensionally defined target points in space could be calculated via a programmed portable Epson HX-20 computer (Radionics, Burlington, Ma, US) in the operating room. Lastly, to allow verification of the established points and positions prior to surgery using a dummy point on the phantom base.[2]

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Materials and methods

Target coordinates

The BRW frame includes a head ring compatible with CT scanners. This frame is held onto the patient's skull by four vertical carbon fibre posts and nylon-steel set pins[3] for negligible artifact production on the scanner, under local anaesthesia in co-operative adults and under general anaesthesia for children and restless adult patients. The localizer ring is assembled onto the head ring and fixed to the table of the CT scanner. One or

more slices in which the lesion is visible are selected and one or two targets are chosen. The XY co-ordinates of these targets are given by the scanner with regard to the zero co-ordinate in the CT scan frame in the plane of the slice. Simultaneously, on each slice, the XY co-ordinates of the nine points representing the slices of the edges and diagonals of the localizer define the plane of the slice with regard to the plane of the head ring. The data is entered into the portable pre-programmed Epson HX-20 computer which then prints out the AP, LAT, and VERT co-ordinates (Fig 1).

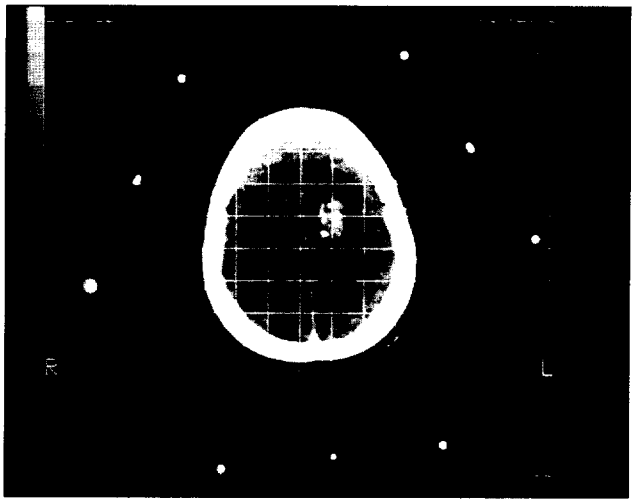

Fig 1. Transverse CT scan of the patient with glioma in the left parietal region. Target in the centre of the grid with 9 fiducial points obtained by BRW stereotactic head ring and BRW localizer.

Pre-operative preparation

Two grams of ceftriazone were given intravenously as a single bolus dose just before the procedure, and those with tumours received dexamethasone and dilantin 48 hours before the procedure. Patients had the procedure and the possible risk of bleeding and other post-operative complications clearly explained to them.

Surgical procedure

The head ring was fixed to the operating table using a Mayfield adaptor, with the head positioned towards the surgeon. The patient's eyes were covered with blenderm (3M Medical, St Paul, Mn, US) and the patient's head and head ring prepared with chlorhexidrine (Delta West Pty Ltd., Bently, WA, Australia) and hibitane solution (Delta West Pty Ltd., Bently, WA, Australia). After draping, the selected entry point on the scalp was infiltrated with local anaesthetic. An approximately 3 cm scalp incision was made, burr hole performed, and dura opened. The BRW arc system was assembled onto the head ring, and the entry point determined by passing the probe through the cannula and the ring block mounted on the BRW arc system until it touched the dura. The side screw on the probe was locked and the BRW arc system removed from the head ring and assembled onto the phantom base.

The vertical rod with vernier markings was then inserted on the phantom base and aligned to the tip of the probe in place. The three co-ordinates (AP, LAT, VERT) from the phantom base were then re-entered into the portable computer which read out the alpha, beta, delta and gamma movements together with the depth of the target calculated from the upper surface of the ring block. These values and the AP, LAT, and VERT co-ordinates printed out initially by the computer from the XY co-ordinates were adjusted on the phantom base and the sterile probe passed to confirm the dummy target point. This allowed extracranial simulation of cranial entry and intracranial target points. The probe tip in all our procedures fell within 1 to 2 cm of the target. The BRW arc system was then removed from the phantom base and tightly assembled onto the head ring. The cannula was inserted into the ring block and the total depth calculated. Then the Nashold side-cutting biopsy forceps (Radionics, Burlington, Ma, US) were passed along the trajectory, and a biopsy obtained. Usually, three to four biopsies were taken from two target points at different depths for tumours.

To drain cerebral abscesses, the radio-opaque ventricular catheter was passed with the stylet into the cannula along the trajectory and punctured the abscess wall. This not only allowed drainage and aspiration, but prevented leakage of pus into the cerebral parenchyma and straying of the catheter tip when the abscess wall collapsed. We also found this procedure useful in craniotomy excision of the thalamic cavernous haemangioma after removing the BRW arc system. Using this entry point approach to the targets we avoided eloquent areas of the brain, Sylvian fissures, and sinuses. Upper pons and pineal lesions were approached through the frontal route, and the lower pons was approached through the suboccipital transcerebellar route. The average operating time was 35 minutes, including the time for histological confirmation.

Materials

Among the total of 65 cases studied retrospectively, there were 47 males and 18 females. The youngest patient was a five-year-old girl and the oldest patient was 70 years old, with a mean age of 44 years. Nine adults and a child received general anaesthesia, and the remaining 55 operations were performed under local anaesthesia. There were 61 lesions in the

supratentorial compartment and these were approached through the cranial vault using the entry point approach. Two lesions in the pons were approached from the cranial vault, puncturing the tentorium with a pointed probe and then a biopsy was taken. Two lesions in the cerebellum were approached through the infratentorial transcerebellar route with the BRW head ring reversed[4,5,15] and the patients in prone position.

Forty-three lesions were located in the cerebral hemispheres (Table 1; 31 males, 12 females) with hemiparesis being the most common presentation (50% of patients). Epilepsy was present in 14 (30%) individuals and syncope and confusion were present in two. Three patients had lesions in the corpus callosum; they presented with headache, epilepsy, and hemiparesis, respectively. Seven patients with lesions in the thalamus and internal capsule presented with hemiparesis, headache, and frontal ataxia. Four patients who presented with visual disturbances and headache had lesions in the suprasellar region and four patients with pineal lesions presented with diplopia and gaze palsy. Another four patients had lesions in the brain stem[6] and they presented with cranial nerve palsies, hemiparesis, and headache (Table 2).

Table 1. Location of lesions in the cerebral lobes

Location	Right	Left
Frontal	6	6
Temporal	7	3
Parietal	9	10
Occipital	1	1
Total	23	20

Table 2. Distribution of lesions in the brain

Location	No.
Cerebral lobes	43
Corpus callosum	3
Thalamus and capsule	7
Suprasellar mass	4
Pineal	4
Brain stem	4
Total	65

Results

Sixty-three patients had a frozen section histological diagnosis at the time of surgery. Thirty patients with hemispheric lesions had no additional neurological deficit related to the procedure. A patient with cerebral sparganosis in the parietal lobe was cured after stereotactic biopsy and excision. A 54-year-old patient with neurocysticercosis in the occipital lobe was treated with praziquantel 600 mg (three times daily) for two weeks after scolex of the pork tapeworm, Taenia solium were identified from the biopsy. Apart from three patients with pyogenic cerebral abscesses, a 5-year-old girl with multiple tuberculous abscesses[7] in the cerebellum and temporal lobe underwent three stereotactic procedures.[2] She recovered well—with a motor power grade of 3 of 5.

Of the 10 patients with low-grade astrocytoma in the cerebral hemisphere, nine remained stable and one died of the disease process a year later. Among those with high-grade astrocytomas, eight of 11 patients remained stable after radiotherapy and two died after six months. One patient with glioblastoma multiforme in the mesial temporal lobe died from bleeding 24 hours after stereotactic biopsy. Two patients with oligodendroglioma improved neurologically after excision. Eight metastatic tumours and three lymphomas were treated by radiotherapy. A 21-year-old male with intractible seizures for 10 years was found to have a temporal ganglioneuroblastoma. The frequency of seizures was significantly reduced after craniotomy and excision of the lesion. Another patient with a cavernous haemangioma in the frontal lobe had this excised after stereotactic biopsy (Table 3).

All three lesions located in the corpus callosum were astrocytomas. None of the patients experienced any additional neurological deficit after the procedure. There were three astrocytomas, one lymphoma, metastatic tumour, infarct and cavernous haemangioma[8,9] in the thalamus and capsular region. The latter (after stereotactic placement of the ventricular catheter for guidance) was excised through craniotomy without any neurological deficit. An 18-year-old woman with headache and visual impairment developed high fever 48 hours after the stereotactic biopsy for craniopharyngioma with suprasellar extension and calcification. An emergency CT scan showed peritumoural haemorrhage close to the biopsy site and near the hypothalamus. She lapsed into coma while measures were taken to cool down her temperature with fluids and application of hypothermic blankets. The patient rapidly went into cardiac arrest and died despite active resuscitation measures.

Table 3. Treatment of brain lesions and outcome

Diagnosis	No.	Treatment	Outcome	
			Stable	Death
Sparganosis	1	Excision	1	
Neurocysticercosis	1	Praziquantel	1	
Abscess (1 tuberculosis, 3 pyogenic)	4	Drainage	4	
Astrocytoma: grade 1/2	10	Radiotherapy	9	1
Astrocytoma: grade 3/4	11	Radiotherapy	8	2+1*
Oligodendroglioma	2	Excision	2	
Metastatic tumour	8	Radiotherapy	7	1
Lymphoma	3	Radiotherapy	2	1
Ganglioneuroblastoma	1	Excision	1	
Cavernous haemangioma	1	Excision	1	
Reactive gliosis	1		1	
Total	43		37	6

* Death related to surgery

A 65-year-old man had intraventricular meningioma confirmed by stereotactic biopsy. He underwent craniotomy and excision of the lesion, but died from bleeding two days post-operatively. Two pineal germinomas and two astrocytomas responded well to radiotherapy.[10] Although a cryptoccocal abscess in the midbrain of a semi-conscious 37-year-old woman was successfully drained, the patient died one month later from pneumonia (Fig 2). A 64-year-old man with a contrast-enhanced lesion in the lower pons, became confused while an attempt was being made to obtain a biopsy. He died of cisternal haemorrhage and the postmortem examination revealed a gritty tumour in the anterior aspect of the pons which was confirmed histologically as a tuberculous granuloma (Table 4).

Table 4. Clinical summary of three patients who died from bleeding after stereotactic biopsy

Case	Sex/Age	Presenting signs and symptoms	Location of lesion	Histological diagnosis	Cause of death
1	F/18	Hyperpyrexia	Headache, visual impairment	Suprasellar	Craniopharyngioma with calcification haemorrhage
2	M/64	Severe headache	Pons	Tuberculous granuloma*	Cisternal haemorrhage
3	M/65	Right temporal	Right hemiplegia	Glioblastoma multiforme	Haemorrhage (astrocytoma grade 4)

* Postmortem diagnosis

Discussion

The BRW system is simple, minimally invasive, and can be used with all scanners.[11] The advantages of CT-guided stereotaxy over the free-hand biopsy are that there is less manipulation of the brain and resultant trauma from multiple needle punctures, and it can be performed under local anaesthesia. Since the patient is awake throughout the procedure, any complications from the operation can be detected early and any necessary investigation and treatment promptly instituted. The duration of operation is short and there is less risk of the respiratory complications seen with free-hand brain biopsy under general anaesthesia. Post-operative epilepsy, intracerebral haematoma, infection, and CSF seedlings are minimised because of the single trajectory; there is no added neurological deficit and the morbidity rate approaches zero. The positive biopsy rate by frozen section of 98.4% obtained in our study would be considered a very good yield and is comparable to those reported in the literature.[12-14]

Three patients died after stereotactic biopsy—the main complication being bleeding. This gave a 4.7% mortality rate, which is high, given the small number of cases and compared with the accepted mortality rate of 1% to 3% mentioned in the literature. We reviewed the case notes of the three patients who died and observed that the first patient with craniopharyngioma refused to stay in bed immediately after the procedure. When high fever developed the next day she was treated as sepsis. By the time we discovered a small peritumoural haemorrhage on the CT scan, she had lapsed into a coma and subsequently went into cardiac arrest.

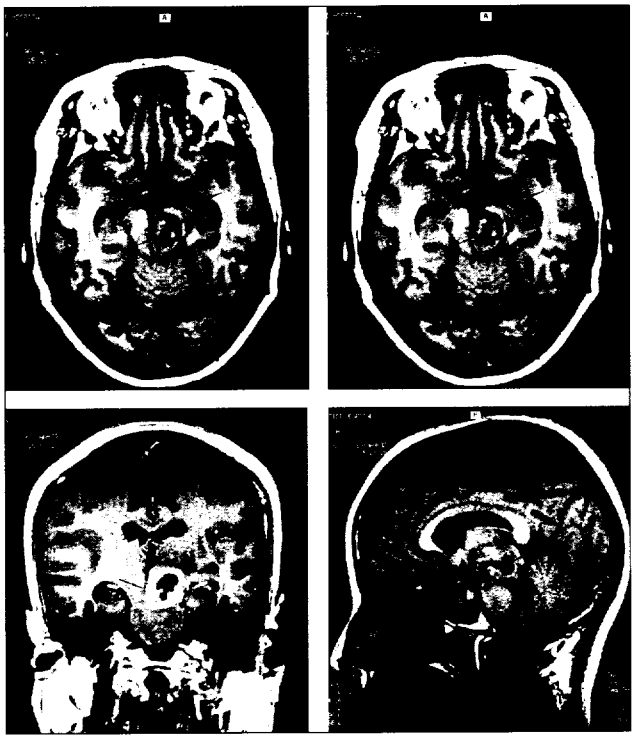

Fig 2. Transverse (T1 and T2), coronal (T2) and sagittal (T2) weighted MRI scan of a patient with a cryptococcal midbrain abscess (arrow)

We advise patients to stay in bed for close observation for at least six hours after the procedure and then allow them to ambulate only when they are neurologically stable. The second patient had a tuberculous granuloma in the anterior aspect of the pons which was approached through the supratentorial route with the biopsy needle passing medial to the incisura. He became restless after the first attempt at taking a biopsy and the procedure was abandoned. He lapsed into coma a few hours after the procedure and died of cisternal haemorrhage. At post-mortem, we discovered that there was no possibility of obtaining a biopsy from a firm, gritty, tuberculous granuloma by stereotactic procedure. Since then we have abandoned this approach for stereotactic biopsy. The third patient had a malignant glioma; multiple biopsies taken from the vascular area probably contributed to the bleeding.

We have now minimised complications by performing procedures under local anaesthesia and by carefully selecting cases. We have recently been using the Cosman-Robert-Wells (CRW-3) stereotactic frame in Kwong Wah Hospital, not only for biopsy but also for evacuating capsular intracerebral haematomas. It is more versatile than the BRW frame and does not require the reversal of the base ring for posterior infratentorial lesions. With intraoperative CT scans and the introduction of newer technology such as the viewing wand, we hope to detect intraoperative complications such as bleeding, and achieve better results through timely operative intervention. Chimowitz et al tried thrombin to control haemorrhage on three patients who developed intractable bleeding during stereotactic biopsy.[15] Although thrombin is effective in stopping intractable arterial haemorrhage during stereotactic brain biopsy, because of its vasospastic activity it can cause cerebral infarction.

Following our retrospective study, we conclude that CT-guided stereotactic neurosurgery is a safe alternative to the conventional approach, but only in experienced hands, and when patients have been carefully screened and made fully aware of the procedure, its complications, and their responsibilities. Close observation during the procedure and post-operatively, by a trained professional are essential for a good outcome.

Mortality rates should be reduced and better results achieved if the amount of surgical experience, patient selection and cooperation, and post-operative monitoring are all considered.

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