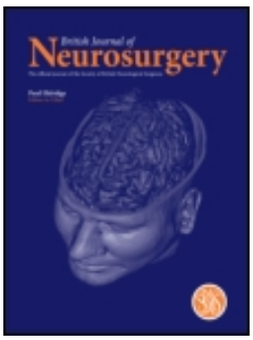

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ORIGINAL ARTICLE

The advantages of frameless stereotactic biopsy over frame-based biopsy

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Abstract
A comparison study is presented, which examines the outcome, complications and cost of stereotactic brain biopsy performed with a frameless versus a frame-based method. The technique of frameless stereotactic biopsy has been shown previously, in both laboratory and *in vivo* studies, to achieve a level of accuracy at least equal to frame-based biopsy. The investigators have validated the technique in a large clinical series. The frameless and frame-based series were concurrent, comprising 76 and 79 cases, respectively. The frameless stereotactic technique involved standard needle biopsy, targeted by an image-guidance system and directed by a novel rigid adjustable instrument-holder. Frame-based biopsies were performed with the CRW and Leksell systems. There were no significant differences in the demographics, lesion site, size and pathologies between the groups. Operating theatre occupancy and anaesthetic time were both significantly shorter for the frameless series than the frame-based series ($p < 0.0001$). In addition, the complication rate in the frameless biopsy series was significantly lower than in the frame-based series ($p = 0.018$). This resulted in lower ITU bed occupancy ($p = 0.02$), shorter mean hospital stay ($p = 0.0013$) and significant cost savings ($p = 0.0022$) for the frameless stereotactic biopsy group, despite the greater use of more expensive MRI in these cases. This comparison study demonstrates that the superior imaging, target visualization and flexibility of the technique of frameless stereotactic biopsy translates into tangible advantages for safety, time and cost when compared with the current gold-standard of frame-based biopsy. The principles are discussed and the authors propose a definition for the term 'frameless stereotaxy'.

Key words: *Comparison study, Computer-assisted surgery, frameless stereotaxy, neuronavigation, stereotactic biopsy.*

Introduction

Frame-based stereotactic biopsy is the current gold-standard technique for the retrieval of histological specimens from targets within the brain. This method provides the neurosurgeon with a safe (mortality <1%, morbidity 3–4%) and effective (diagnostic yield >95%)[1–8] means for biopsy retrieval which has transformed the outcome of this procedure compared with freehand (CT-directed) burr-hole biopsy (mortality >5%, morbidity 15%, diagnostic yield 85%).[9,10] However, the frame-based technique is cumbersome, restricted to point targeting and still carries a small, but significant complication rate.

We have developed a method for frameless stereotactic biopsy that combines the precision of stereotaxy with the ergonomics and practicality of neuronavigation. The technique has been described in detail previously,[11] and the results of laboratory phantom accuracy assessments reported.[12] The accuracy of the frameless stereotactic technique was found to be at least the equivalent of contemporary frame-based methods (mean error of phantom frameless stereotactic biopsy = 1.8 mm, frame-based biopsy = 2.1 mm, for equivalent imaging parameters).[12–14] A preliminary clinical study of this technique revealed how improved image presentation and manipulation facilitated selection of the optimal biopsy target and demonstrated a significant reduction in the duration of anaesthesia.[15] The assessments of accuracy included a study in which the position of the actual biopsy site was identified with post-operative MRI and compared with the intended target site via image fusion. By this means the mean *in vivo* accuracy of frameless stereotactic biopsy was shown to be highly satisfactory at 2.3 mm.[12]

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In this paper we present a clinical comparative study, contrasting this novel technique with the established technique of frame-based biopsy in concurrent series.

Materials and methods

Patient population

Between September 1996 and April 1999, 155 stereotactic biopsy procedures were performed. Seventy-nine of these were undertaken with a stereotactic frame and 76 were conducted with the novel technique of frameless stereotactic biopsy. Selection of the technique for each case was determined by the availability of the image-guidance system (and IGS research fellow). Thus, throughout this period the preferred technique was frameless biopsy with frame-based biopsy employed when this was unavailable (i.e. there was no case selection for either procedure). The patients in the frame-based series (Table I) comprised 49 men and 30 women, aged between 15 and 96 years (mean 52.1). Those in the frameless series comprised 42 men and 34 women, aged between 25 and 79 years (mean 54.9). The imaging modality employed to target the biopsy was CT in 89% of the frame-based procedures and 32% of the frameless operations. Conversely, the imaging modality was MRI in 11% of the frame-based cases and 68% of the frameless ones.

Technique of frame-based stereotactic biopsy

The stereotactic frames employed were the Cosman–Roberts–Wells (CRW, Radionics, Burlington, USA) and the Leksell (Elekta Instruments, Stockholm, Sweden) systems. All biopsies were performed under general anaesthetic, induced prior to application of the base ring. Patients were transferred to the scanner with full monitoring and intravenous anaesthesia, returning to the operating room for the surgical procedure. The CT protocol comprised acquisition of a block of axial slices of 2 mm slice thickness with 3 mm slice spacing, following intravenous injection of contrast. The MRI protocol comprised acquisition of a full head gadolinium-enhanced T1-weighted volume of 80 slices giving a slice thickness of 1.5 mm.

TABLE I. Patient demographics and imaging modalities for the frameless and frame-based biopsy series

		Frame-based series	Frameless series	Combined series
Number	*n*	79	76	155
Gender	Male	49	42	91
	Female	30	34	64
Age (years)	Range	15–96	25–79	15–96
	Mean	52.8	54.9	53.8
	SD	15.9	14.7	15.3
Scan Modality	CT	89%	32%	59%
	MRI	11%	68%	41%

Technique of frameless stereotactic biopsy

The neuronavigation system employed was Easy-Guide Neuro™ (Philips Medical Systems Nederland BV, Best, The Netherlands), an infra-red LED-based system. A stereotactic guide was developed,[11] which would adapt to a variety of instruments, was freely adjustable to reach all parts of the cranium, would lock in place rigidly and allowed fine correction of the trajectory setting (Fig. 1). The guide arm was fixed to the Mayfield clamp (OMI Surgical Products, Cincinnati, USA) and the joints of the arm locked simultaneously without producing torsional movement.

The method developed for frameless stereotaxy comprised six stages, namely (i) image acquisition, (ii) image to patient registration, (iii) entry point selection, (iv) burr hole construction, (v) target and trajectory definition, and (vi) biopsy retrieval. This technique has been described in detail previously.[11,16] In summary, self-adhesive scalp fiducials were applied prior to imaging with either Gadolinium-enhanced MRI or contrast-enhanced CT with standard IGS protocols (MR; SPGR sequence with minimum TR and TE, flip 50°, matrix 256 × 256, FOV 24 cm and slice thickness 1.5 mm, CT; helical scan with matrix of 512 × 512, FOV 20.5 cm, gantry tilt 0° and slice thickness 3 mm). The patient was positioned and a Mayfield head clamp applied. Image to patient registration was performed with a fiducial-based method. The entry point was selected using a hand-held pointer and virtual elongation to display the trajectory and potential target sites (Fig. 2). Distance to target was calculated, depth stop

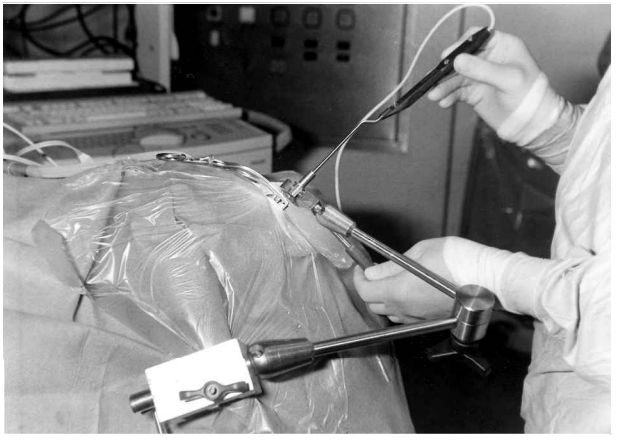

FIG. 1. Target and trajectory selection with the frameless stereotactic technique. The instrument holder is attached to the Mayfield head clamp (foreground) and the arm is locked in position over the burr-hole. An IGS pointer is seen docked in the trapped ball, which allows fine adjustment of the trajectory.

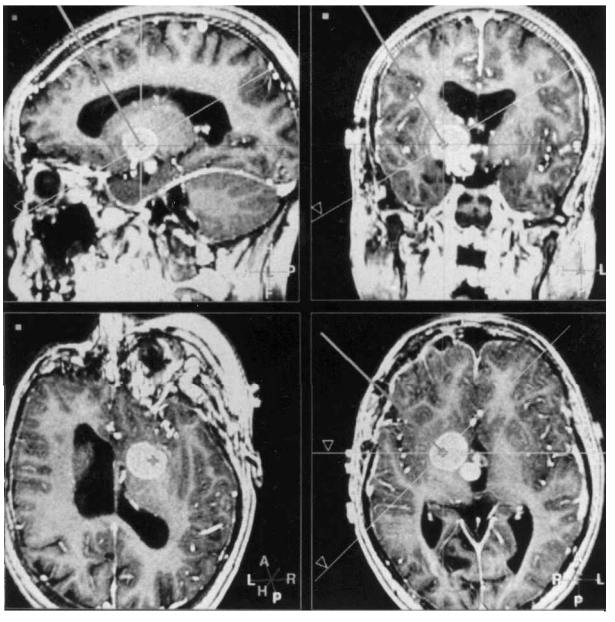

FIG. 2. MR images from a case in the frameless stereotactic biopsy series. The pointer tip (at the skin surface) is extended with virtual pointer elongation to display the target and trajectory for biopsy. Sagittal, coronal and axial reformats reveal the detailed anatomy of the target site, whilst the perpendicular pointer view (lower left image) allows the surgeon to 'walk' along the trajectory to the target and beyond.

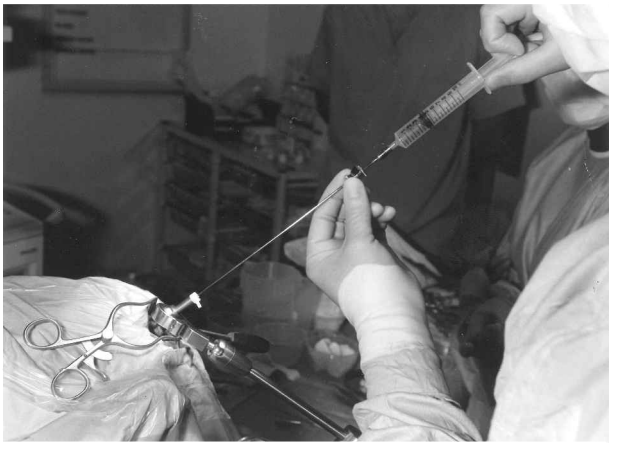

FIG. 3. Biopsy retrieval with the frameless stereotaxy technique. The adjustable, adaptable instrument-holder locked in position rigidly allowing reliable and repeatable target localization.

positioned on the biopsy needle (Sedan–Nashold side cutting needle, Radionics Inc., Burlington, USA) and specimens retrieved from each quadrant as performed normally. (Fig. 3).

Cost analysis

The cost of inpatient days, surgery for stereotactic biopsy and imaging studies were obtained from the hospital finance department (Table II). The number of days spent by each patient on the ward and in ITU was determined from inpatient and ward records. Additional imaging was defined as that which was obtained during the immediate postoperative period through clinical necessity (i.e. mainly following the occurrence of a complication). The minor differences in the protocols for MRI and CT acquisition for the two biopsy techniques did not have any financial impact, as scanning times were similar. However, the fiducial markers each cost £1 leading to an average additional cost of £10 per frameless stereotaxy case.

TABLE II. Hospital costings (GB£) for in-patient stay, surgery and imaging

	Cost (£)
Admission (Neurosurgical Ward 24 h)	380
Admission (ITU 24 h)	1350
Operation (frame-based stereotactic biopsy)	4650
Operation (frameless stereotactic biopsy)	4650
CT scan	150
MRI scan	500
CT scan (+ fiducials)	160
MRI scan (+ fiducials)	510

Capital costs per case were derived for each technique by determination of the purchase costs, annual service charges, equipment lifetime and number of cases per annum. The CRW lifetime was known to be 10 years, as this was the interval from first acquisition to replacement in our Institution. The image-guidance lifetime was presumed to be similar. The proportion of the capital costs borne by the frameless biopsy cases was calculated from the ratio of biopsies per annum (frameless and frame-based) to open image-guided cases per annum (50%). The proportion of the capital costs borne by the frame-based biopsy cases was 100% of the frame costs.

Image and data analysis

Much of the patient and clinical data were collected prospectively and supplemented by review of the case notes for each patient, examination of the preoperative brain scans and pathology from the histology database. The maximum dimension of each lesion was measured, the depth of the lesion below the nearest skin surface ascertained (method described in detail previously[12]) and the lesion classified according to the lobe(s) involved, side, eloquence and brain structure(s) affected. The duration of the anaesthetic was obtained from the anaesthetic records and the duration of surgery from the operating room computer log. Intra-operative complications were discerned from the surgeon or operation notes and postoperative complications clinically, from the ward records and pathology service records.

The results were analysed for patterns, correlation and significance as a whole, and when segregated according to operation type. The statistical tests of

significance employed were unpaired two-tailed *t*-tests for normally distributed data and χ^2 tests for non-continuous data (significance established when $p < 0.05$).

Results

Radiological characteristics of the lesions

Examination of the imaging studies revealed that the distribution, dimensions and locations of the lesions were similar for the frame-based and frameless series (Table III). The mean lesion diameter was 37 mm (range 8–80 mm, SD 15.8), the lesion was in the cerebral hemispheres in 87%, the diencephalon in 9% and the brainstem/cerebellum in 4%. The lesion was on the right in 45% of cases, on the left in 42%, midline in 10% and bilateral in the remaining 3%. In 88% of cases the lesion was single and in 12% there was more than one lesion. The lesions were cortical in 8%, subcortical in 32% and deep in 60%. This distribution was seen in both the frame-based and frameless series cases. The depth of the lesions below the nearest skin surface was found to be significantly greater in the frame-based series (mean 47.2 mm, SD 20.6 mm) than in the frameless series of cases (mean 35.2, SD 18.6, $p < 0.0001$). There was, however, no difference between the groups in the frequency of lesions within eloquent regions.

TABLE III. Imaging characteristics for the lesions in each series

	Frame-based series	Frameless series	Combined series
Laterality			
Right	41%	47%	45%
Left	41%	42%	42%
Midline	14%	8%	10%
Bilateral	4%	3%	3%
Location			
Telencephalon	84%	90%	87%
Diencephalon	10%	8%	9%
Rhombencephalon	6%	2%	4%
Multifocal	34%	14%	24%
Site			
Cortical	4%	11%	8%
Subcortical	27%	36%	32%
Deep	69%	53%	60%
Number of lesions			
Single	88%	87%	88%
Multiple	12%	13%	12%
Lesion diameter (mm)			
Range	8–80	8–79	8–80
Mean	34.8	38.7	37
SD	16.2	15.4	15.8
Lesion depth (mm)			
Range	11–102	7–102	7–102
Mean	47.2	35.2	40.5
SD	20.6	18.6	20.3

Pathological diagnosis

The spectrum of disease encountered in each of the biopsy series was representative of a general, unselected group of neurosurgical patients. There were no significant differences between the proportions of pathologies between the frame-based and frameless series. The final pathological diagnosis was classified into high grade glioma, low grade glioma, other tumour, inflammatory and non-diagnostic groups. In the frame-based series there were 47 high grade gliomas (60%), 13 low grade gliomas (16%), 10 other tumours (13%), five inflammatory conditions (6%) and four cases (5%) without a pathological diagnosis (Table IV). In the frameless series there were 52 high grade gliomas (68%), six low grade gliomas (8%), 12 other tumours (16%), five inflammatory conditions (7%) and one case without a pathological diagnosis (1%).

Comparison of the smear specimen diagnosis with the final pathological diagnosis for each case and for each series revealed similar results for the two series. The correct diagnosis was reached on smear examination in 130 (87%) of the 150 diagnostic specimens. These rates were similar for both frame-based and frameless series, and compare well with the rates quoted in the literature.[17–19]

TABLE IV. Histological results for the frame-based, frameless and combined series with pathological classification

Classification	Pathology	Frame-based series	Frameless series	Combined series
High grade glioma	Glioma grade III–IV	47	52	99
Low grade glioma	Glioma grade I–II	13	6	19
	Lymphoma metastasis	4	5	9
		3	5	8
Other tumours	Pineal tumour	2	1	3
	Neuroma craniopharyngioma	1		1
			1	1
	Abscess	1	1	2
Inflammatory conditions	Multiple sclerosis	1	1	2
	PML/HIV	1	1	2
	Cysticercosis		1	1
	Radionecrosis	1		1
	Vasculitis	1	1	2
Non-diagnostic	No result	4	1	5

Duration of operation

Whilst the duration of anaesthesia and surgery were almost identical in the frameless series, in the frame-based series the anaesthetic time included scan acquisition and was therefore considerably longer than the duration of surgery. For the frameless cases the procedure (operation and anaesthetic) lasted for between 20 and 180 min (mean 54.2, SD 23.6), whilst for the frame-based procedures the duration of anaesthesia ranged from 80 to 235 minutes (mean 127.4, SD 31.9). The duration of the operation in the frame-based series ranged from 25 to 145 minutes (mean 56.3, SD 17.5). Thus, the mean duration of the anaesthetic was significantly longer in the frame-based than the frameless series ($p < 0.0001$), but there was no significant difference in the duration of surgery between the two groups (Fig. 4).

Complications

In the frame-based series 22 patients experienced one or more complication (Table V). There were five haemorrhages with one fatality from a deep hemisphere haematoma. In one of these cases the burr hole was extended to a craniectomy to control biopsy site bleeding. Three patients suffered permanent neurological deficits from haemorrhage and one patient suffered a transient deficit. In seven other cases there was a transient deterioration in neurological status due to increased vasogenic oedema following surgery and two patients, who had not previously had fits, suffered epileptic seizures. There were eight postoperative infections (three chest infections, two urinary tract infections, one wound infection, one peritonitis following duodenal ulcer perforation, one septicaemia secondary to prolonged ventilation after haemorrhage). There were also two cardiac complications (one transient left ventricular failure and one sinus arrest) and one gastro-intestinal complication (the perforation of a duodenal ulcer).

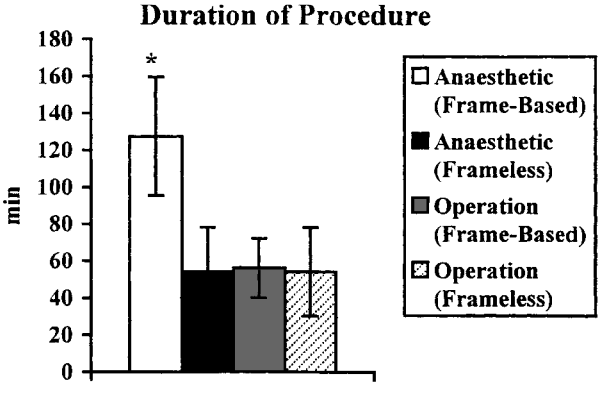

FIG. 4. Bar graph showing the mean duration of anaesthesia for both the frame-based and frameless series (error bars denote ±1 SD).

In the frameless biopsy series 11 patients experienced complications. There were no cases of clinically significant haemorrhage. Seizures occurred in five cases following surgery, three of whom had not previously experienced fits. In four cases there was deterioration in neurological status due to increased vasogenic oedema (one permanent deterioration, three transient). One patient suffered an infectious complication, succumbing to pneumonia 2 months postoperatively, following a prolonged period on the ITU. One patient experienced gastritis that resolved following withdrawal of dexamethasone and one patient developed hypertension, requiring the introduction of new medication.

Whilst the overall complication rate for the frame-based series was 22% and that for the frameless series was significantly lower at 14% ($p = 0.0183$), the rate of surgical complications was 8.8 and 6.6%, respectively (Table V). There was one fatality in each series; there were significantly more haemorrhagic complications and significantly more permanent neurological deficit in the frame-based series than the frameless series (overall significance $p = 0.0008$). There were also more infective complications in the frame-based series.

Cost analysis

The hospital accountants made no distinction between frame-based and frameless biopsy for procedural costs (£4650 each, Table VI. Although MRI was used more often and there was a small additional cost (£10) for each frameless biopsy due to the use of fiducials, the mean cost per case for frameless stereotactic biopsy (£6723) was signifi-

TABLE V. Complications occurring in the Frameless and Frame-Based biopsy series

Complication	Frame-based series	Frameless series	Combined series (%)
Death	1	1	2 (1.3)
Haemorrhage (clinically significant)	5	0	5 (3.2)
Permanent neurological deficit	3	1	4 (2.5)
Transient neurological deficit	8	3	11 (7.0)
Epilepsy (new)	2	5	7 (4.5)
Infection	10	1	11 (7.0)
Other system complications	3	2	5 (3.2)
Total	22	11	33 (21.3)

TABLE VI. Mean costings (GB£) per case for both of the biopsy series

	n Frame-based	Cost (£)	*n* Frameless	Cost (£)
Operative procedure	1	4650	1	4650
ITU stay (mean days)	0.34	456	0.07	96
Ward stay (mean days)	6.22	2365	4.03	1531
CT scans (mean number)	1.19	179	0.43	69
MRI scans (mean number)	0.16	81	0.74	377
Capital costs (per case)		193		186
Total		7731		6723

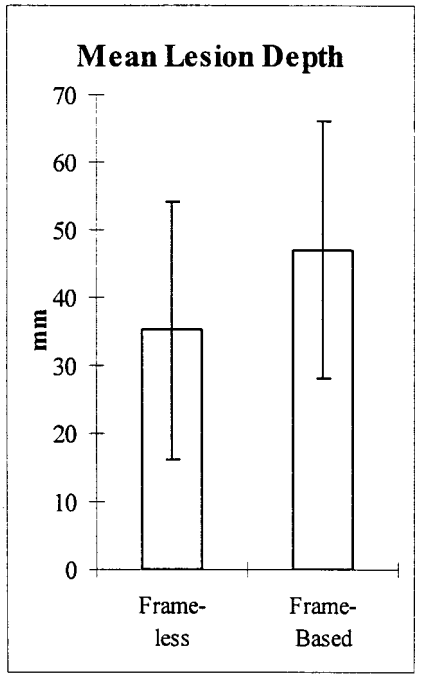

FIG. 5. Bar graph demonstrating the mean depth of lesion below skin surface for the frameless and frame-based biopsy series. There was a significant difference between the means ($p < 0.0001$, two-tailed t-test), but considerable overlap (error bars denote ±1 SD).

cantly lower than the mean cost per case for frame-based biopsy (£7731, $p = 0.0022$). This arose through the significantly longer mean duration of hospital stay in the frame-based series (6.5 days) than in the frameless series (mean 4.1 days, $p = 0.0013$). Since the hospital stay for uncomplicated cases was similar for both series this difference reflected the higher incidence of complications in the frame-based series. In addition, the mean ITU stay in the frame-based group (0.33 days) was also significantly greater than that for the frameless group (0.07 days, $p = 0.02$).

Capital costs for the frame-based series were purchase cost (£86,698 for CRW equipment) and service contract (£2500 per annum). The frame was replaced at 10 years and we performed 60 biopsies per annum, resulting in a per case capital cost of £186.16 for frame-based biopsy. Capital costs for the frameless series were purchase cost (£107,000 for the basic cranial system) and service contract (£12,500 per annum). We performed 60 biopsies and 120 open image-guided operations per annum, thus attributing 50% of the navigation equipment costs to the biopsy cases. The equipment lifetime was taken as 10 years resulting in a per case capital cost of £193.33 for frameless biopsy.

Discussion

Development of biopsy techniques

Even in the CT era freehand burr-hole biopsy carried a mortality rate of over 5% and diagnostic yield of only 85%.[9] Fortunately, this technique has been superseded by the advent of stereotactic biopsy, which carries a mortality rate of below 1%, a serious morbidity rate of 3–4% and a diagnostic yield of over 95%.[1–8] There are, however, intrinsic limitations to frame-based biopsy. Specifically frame-based systems are point-based, require complex calculations for each target, employ large cumbersome structures and require scanning within the frame (i.e. at the time of surgery). Over the last decade image-guidance systems (IGS) have been developed which provide rapid image reformats to display target positions interactively. These systems are intuitive, accurate and rapid. However, image-guidance workstations are essentially scan-display systems and are not stereotactic devices. A number of groups have used IGS to direct hand-held biopsy retrieval,[20] but this is a retrograde step, whereby the proven accuracy of frame-based biopsy is abandoned for freehand biopsy (albeit with image-guidance).

Our group have developed a system that combines image-guidance and stereotaxy to exploit the advantages of each and overcome their intrinsic disadvantages. Concurrently, other groups have also developed arm-based systems for frameless stereotactic biopsy,[21–23] but none have satisfactorily demonstrated the laboratory and *in vivo* accuracy of their method, and several of these arms clearly either lack manoeuvrability or sufficient rigidity for widespread adoption. By contrast our system has a very simple and ergonomic design and has proven accuracy that compares favourably with frame-based biopsy.

Defining frameless stereotaxy

Whilst there used to be no doubt over whether a technique was stereotactic or not (a stereotactic frame was either used or was not) the introduction of IGS has brought some confusion in this regard. If, however, stereotaxy is defined as 'a system by which an instrument may be advanced directly to a pre-selected discrete target, without deviation or collateral brain injury' it becomes clear that an instrument guide that fixes rigidly, aligns accurately and guides instruments reliably is fundamental. Hand-held methods are ipso facto not stereotactic. Our group were able to successfully combine IGS and stereotaxy through development of an arm which satisfied these requirements[11] and we propose that 'frameless stereotaxy' is a useful term when applied strictly to point-targeted arm-based IGS techniques.

Accuracy

The mean error of the technique of frameless stereotaxy assessed via laboratory tests[12,24] was 1.3 mm (SD 0.6 mm). The mean error for 3 mm helical CT was 0.9 mm (SD 0.5 mm) and that for 1.5T MRI was 1.3 mm (SD 0.6 mm). In these tests, accuracy closely paralleled the voxel size of the scans employed. Slice thickness was similarly found to be the major determinant of error by Maciunas and coworkers in their landmark tests of frame accuracy.[13,14] They found the application accuracy of the CRW frame to be 1.8 mm (SD 1.1, 95% CI 3.6 mm) and with comparable scanning parameters the accuracy of frameless stereotaxy was 1.1 mm (SD 0.5 mm, 95% Cl 2.1 mm). Our studies also revealed the mean *in vivo* error of frameless stereotaxy to be 2.3 mm (SD 2.0 mm) with both CT and MRI guidance.[12] There are no comparable *in vivo* accuracy measurements available for frame-based biopsy with which to compare. A further study[25] examined the impact of postimaging brain distortion in a wide variety of IGS cases and these results indicate that brain shift would have no significant impact on the accuracy of frameless stereotaxy.

Advantages of frameless stereotaxy

The technique of frameless stereotaxy was universally popular in our Department, owing mainly to (i) the temporal separation of imaging from surgery (making the surgical procedure rapid and simple) and (ii) the enhanced image presentation for target selection. In addition, the frameless technique enabled MRI-directed biopsy to be employed more often (there is no need for MRI-compatible equipment), multiple target selection was undemanding and frame fixation was not required. In this study, comparing 79 frame-based biopsies with 76 frameless stereotactic biopsies we found distinct advantages with the frameless technique. Anaesthetic time (and so theatre occupancy) were dramatically reduced (>50% reduction, $p < 0.0001$) as previously described,[15] complications were significantly fewer (50% reduction, $p = 0.0008$) and these combined to make frameless stereotactic biopsy significantly cheaper than frame-based biopsy (15% cost saving, $p = 0.018$). Most interestingly, analysis of the capital costs per case for these techniques revealed that there was little difference between frame-based and frameless costs when the additional uses of the navigation equipment were taken into account. Although the rate of complications for frame-based biopsy appears relatively high this reflects the inclusion of all clinical events whether directly related to surgery or not. In addition, detection of complications with prospective collation is inevitably greater than in the retrospective reports found in the literature[26] and certain complications (e.g. haemorrhage) have been shown to occur at a very high incidence, but usually remain undetected.[27] Nonetheless, the possibility remains that the high rate of adverse events in the frame-based series is related to relative inexperience of the operators, whereas the novel technique may have been more closely supervised. Although some of the time differential between the techniques is dependent upon the use of a general anaesthetic and patient transfer, the advantages of temporal separation of scanning and imaging plus the detailed image presentation and ease of target selection remain pertinent for frameless biopsy, whichever anaesthetic technique is employed.

MRI was employed more often in the frameless series, taking advantage of the superior anatomical information and avoidance of ionising radiation possible by this technique, without the penalties of major image-distortion, equipment costs and complexity associated with frame-based MRI biopsy.[28] Whilst MRI is acknowledged to have inferior spatial geometry compared with CT, these errors are low at the centre of a target volume, may be minimized by careful selection of the imaging parameters and are much reduced in frameless cases by the absence of frame-induced distortion.[29,30] In addition, CT scans are by no means free of geometric distortion[29] and the improved visualization of targets may in large part explain the superior results of frameless stereotaxy.

In this study two techniques of stereotactic biopsy were compared. The most appropriate imaging modality and target were chosen in each individual case with no attempt to standardize these. Thus, MRI was more readily available in the frameless series with the advantages stated above. Similarly, the target was selected by reference to 2D slices in the frame-based series and with orthogonal reformats in the frameless series. The

consequence of this was that the series did not compare two techniques of reaching the same target, rather two methodologies were compared, including their intrinsic constraints or lack of restrictions. This enabled the relative merits of frameless stereotactic biopsy to be demonstrated fully.

Conclusions

Frameless stereotactic biopsy is a simple, effective and intuitive technique which provides the advantages of reduced anaesthetic time, lower cost and fewer complications when compared with traditional frame-based stereotactic biopsy. The term 'frameless stereotaxy,' should only be applied to methods of image-guidance where instruments are directed with stereotactic precision to a preselected target by a navigation system, and not to hand-held methods.

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None of the authors has any financial interest in the devices presented in this article.

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