Frameless Navigated Biopsy with the BrainLAB® VarioGuide System: A Technical Note

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Frameless Stereotactic Brain Biopsy Procedures Using the Stealth Station: Indications, Accuracy and Results

Neuronavigationsgestützte Hirnbiopsie mit der Stealth Station: Indikationen, Genauigkeit und Ergebnisse

Abstract

This study presents the results of 57 stereotactic brain biopsies using a frameless neuronavigation system, the Stealth Station. The supratentorial lesions had a mean diameter of 33 mm and a mean distance of 32 mm from the entry point at brain surface. In all cases the stereotactic procedure was planned in the preoperative 3-D magnetic resonance data set. In seven cases additional data for identification of eloquent brain areas was integrated from magnetoencephalography or functional magnetic resonance imaging. During surgery the samples were sent to neuropathological examination and the operation completed after the confirmation of pathological tissue. Using this method, in 56 cases a pathological tissue was obtained and a diagnostic yield of 98 % was achieved. In two cases (3.5 %) a new neurological deficit remained (hemiparesis and visual field deficit). The mean operation time was 92 minutes including examination of frozen sections.

The results of our series demonstrate, that frameless stereotactic systems can also be reliably applied for biopsy of supratentorial lesions larger than 15 mm.

Frameless stereotaxy in combination with intraoperative pathological confirmation is a safe and reliable method for stereotactic brain biopsy with a diagnostic yield comparable to frame-based stereotaxy.

Key words

Frameless stereotaxy · image-guided surgery · neuronavigation · stereotactic brain biopsy

Zusammenfassung

In der vorliegenden Studie werden die Ergebnisse von 57 stereotaktischen diagnostischen Biopsien unter Verwendung der Stealth Station vorgestellt. Die Planung der Operation erfolgte anhand von dreidimensionalen Magnetresonanzdatensätzen, in sieben Fällen wurden zusätzlich die benachbarten eloquenten Hirnareale mittels Magnetoenzephalographie oder funktioneller Magnetresonanztomographie dargestellt und in die Neuronavigation integriert. Die biopsierten supratentoriellen Läsionen wiesen einen mittleren Durchmesser von 33 mm auf und lagen im Mittel 32 mm unter der Cortexoberfläche. Intraoperativ erfolgte eine Schnellschnittbefundung des Biopsats. Mit dieser Methode konnte in 56 der 57 Fälle (98 %) pathologisches Gewebe gewonnen werden. In zwei Fällen kam es zu einer bleibenden neurologischen Verschlechterung (Hemiparese, Gesichtsfelddefekt). Die mittlere Operationsdauer betrug 92 Minuten.

Diese Studie zeigt, dass die rahmenlose Stereotaxie unter Verwendung der intraoperativen Schnellschnittdiagnostik eine zuverlässige Methode zur Biopsie supratentorieller Läsionen mit einem Mindestdurchmesser von 15 mm darstellt und in der diagnostischen Sicherheit der klassischen rahmenbasierten Stereotaxie nicht nachsteht.

Schlüsselwörter

Neuronavigation · rahmenlose Stereotaxie · stereotaktische Hirnbiopsie

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Introduction

Stereotactic brain biopsy is a well-established procedure to sample tissue from nearly any location of the brain for neuropathological diagnosis [7, 8, 11, 13]. It is still a domain of the traditional frame-based devices allowing a precise tissue sampling within the intracranial space. The frame-based procedure, however, has some disadvantages so that frameless stereotaxy as a relatively simple and intuitive method gets increasingly popular in neurosurgery. The fixed stereotactic frame is replaced by tracking of instruments in a stereotactic 3-D space which is defined by a registration of the physical space with 3-D image data. Several studies showed that the clinical application accuracy of these frameless stereotactic systems, also known as neuronavigation, is comparable to classical stereotactic frames [3, 23, 30]. Frameless stereotaxy may be an alternative to the classic frame-based method for brain biopsy in selected cases [6, 12, 17, 25, 31]. However, the equivalence of both methods with regard to clinical accuracy and diagnostic yield has still to be proved. Furthermore, frameless stereotactic systems lack a satisfactory device for a rigid fixation of the guidance cannula, so that biopsies of deep-seated lesions located e.g. in the brain stem are not advisable.

We summarize our experience in frameless stereotactic brain biopsy during the last 5 years with focus on diagnostic yield, practicability and outcome.

Methods

Patient population

Between November 1996 and September 2001 we performed frameless stereotactic brain biopsy in 57 patients with supratentorial lesions. Patient age varied between 8 and 77 years (mean 51 years). Male patients were predominant (65%). The maximal lesion diameter in the preoperative images ranged from 15–51 mm (mean: 33 mm). The mean trajectory distance from the entry point at the brain surface to the target point was 32 mm (range 15–55 mm).

In all cases the resection of the lesion was not intended for various reasons, such as: multiple lesions, poor general condition, extent of the lesion in eloquent or inaccessible brain areas or in suspected lymphoma. In 8 cases (14%) preoperative imaging revealed multiple lesions. In these cases only the most assessable lesion was chosen. The localization of the operated lesions is summarized in Table **1**.

Imaging

In all cases we used a 0.2 Tesla Magnetom Open scanner (Siemens Medical Solutions AG, Erlangen, Germany) for preoperative imaging. The T1-weighted 3-D-FLASH gradient echo sequence (FLASH: fast low angle shot, TE: 7.0 ms, TR: 16.1 ms, flip angle: 30°, slap 168 mm, 112 slices, FOV: 250 mm, matrix: 256×256) allowed multiplanar reformatting. The imaging was performed one day before or immediately prior to surgery. In seven cases additional information for the identification of eloquent brain areas was integrated from magnetoencephalography (MEG) or functional magnetic resonance imaging (fMRI) [10, 24].

Table **1** Patient characteristics

	mean	***range***	***SD***
number of patients	57		
age (years)	51	8–77	15
sex (male/female)	37/20		
localization of lesion		no. of cases	
frontal		21 (36.8%)	
parietal		13 (22.8%)	
temporal		11 (19.2%)	
occipital		10 (17.5%)	
corpus callosum		3 (5.3%)	
ventricle (lllrd)		1 (1.8%)	
left/right/medial		26/27/4	

SD = standard deviation

Navigation

Intraoperative image guidance was achieved using a pointer based navigation system (Stealth Station, Medtronic, Broomfield, CO, USA). The guidance tube with LEDs for tracking allows placement of the biopsy needle in 3-D orientation according to the straight trajectory which is planned with the navigation system's software by defining an entry and target point [15, 16, 29]. The system calculates registration accuracy, given as root mean square error (RMSE), using a matching algorithm after successful registration of 6–10 disposal skin fiducials. The algorithm compares the relationship of the fiducials position on the images with that on the patients head during registration procedure before surgery [28].

Surgery

The 57 procedures were performed by two board certified neurosurgeons. In all cases a single burr hole trepanation was performed. In selected cases, high-risk structures, such as eloquent cortex (detected in MEG or fMRI) or blood vessels were segmented for intraoperative visualization. The precise placement of the tip of the guidance device was defined as the entry point of the trajectory. After definition of the target point the trajectory and the distance from the entry point to the target were calculated by the navigation system. The guidance device including the guide tube were affixed to a Leyla retractor, positioned, and then aligned to the trajectory (Figs. **1** and **2**). This alignment was facilitated by a so-called "guidance view mode" in which entry and target point, displayed as circles, were brought into congruence. After inserting the biopsy needle to the calculated depth, measured on the scale of the needle and the software, a tissue biopsy was taken with a side cutting needle under aspiration. The tissue sample was then brought to the neuropathological laboratory. The time for neuropathological frozen section ranged between 28 to 43 min. In case of a positive pathological result a second biopsy was taken from the same area for final examination. In case of unclear or normal pathological findings in the frozen section, the target area was modified and another biopsy was taken via the same burr hole. All patients were followed up on the intensive care unit postoperatively.

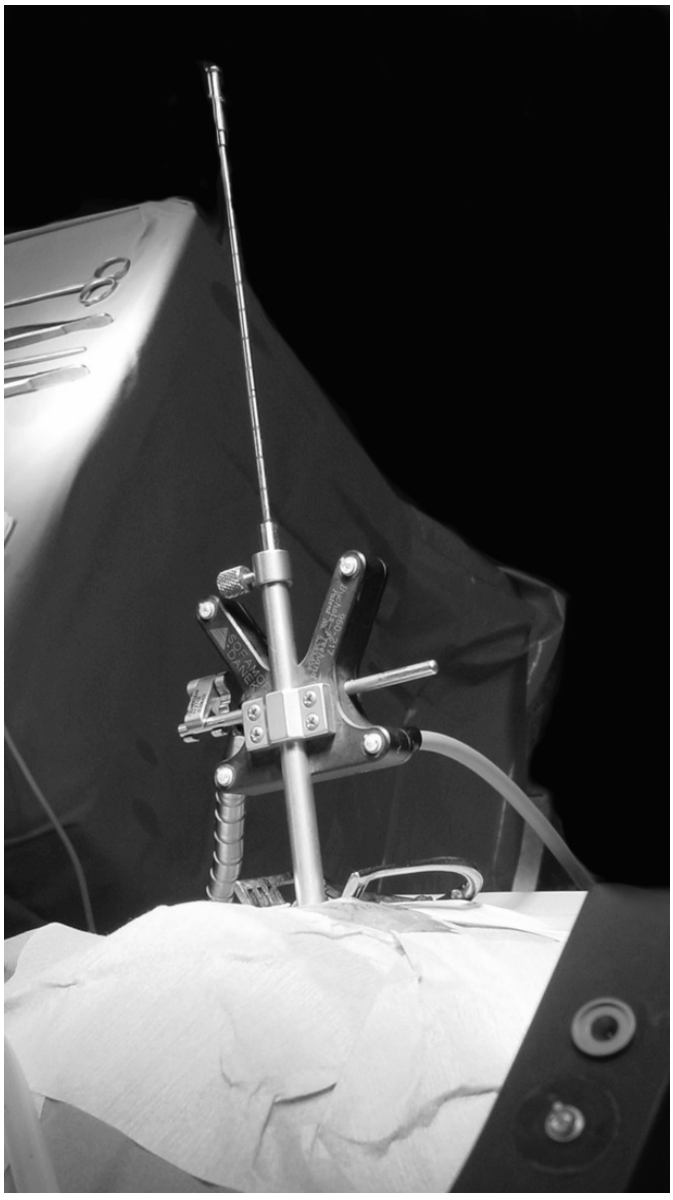

Fig. **1** Operative set up of frameless stereotactic brain biopsy: A side cutting needle is inserted through a guide tube which is tracked by LEDs. The surgical trajectory and distance to target is defined by fixation of the guide tube in alignment with the planned trajectory in the software module.

Table **2** Navigational Data

	mean	*range*	*SD*
number of fiducial markers	8.5	6–10	1.6
root mean square error (mm)	1.1	0.5–3.2	0.7
operation time (min)	92	29–196	32.5

SD = standard deviation

Results

Clinical application and accuracy of the navigation system

The applicability of the navigation system proved to be feasible for all procedures. Preoperative system setup including the registration process lasted 10 minutes on average. The mean registration error (RMSE) was 1.1 mm (range: 0.5–3.2 mm). Anatomical landmark checks showed in all cases satisfactory clinical accuracy. In a previous phantom study we found the 95th percentile for the localization error was 2.7 mm for the Stealth Station [30].

The mean operation time from skin incision to closure was 93 min, ranging from 30 min to 196 min (Table **2**). In the three operations of brain abscesses the operation time was significantly shorter, ranging from 30 min to 45 min (mean 40 min). In these cases the aspirate was sent to the department of microbiology after surgery.

Histological findings and surgical outcome

The number of biopsies ranged from one to five samples (mean 2.3). In 44 (77%) cases first biopsy obtained pathological tissue and after a final sample operation was completed. In 55 of the 57 cases (96.5%) the final histological result allowed a definitive neuropathological diagnosis. Most of the lesions were neoplastic (88%), with a majority of high-grade gliomas (52% of the diagnosed tumors).

Only in one case where the frozen section examination suggested a glioma, the final examination, however, was not able to establish a definitive diagnosis. In another case the frozen section examination revealed metastasis but the amount of tissue

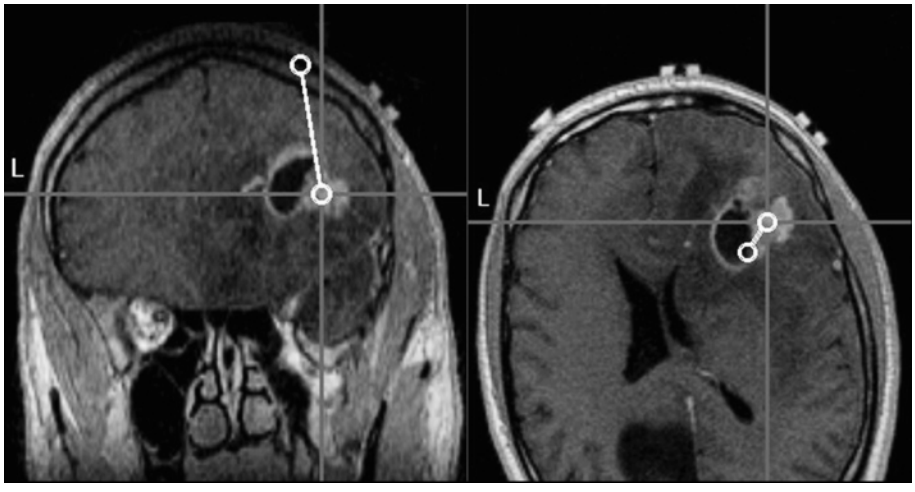

Fig. **2** Planned trajectory for frameless stereotactic brain biopsy in a patient with left frontal cystic glioblastoma.

Table **3** Histological evaluation

	histology	*grade*	*no. of cases (%)*
neoplasm	astrocytoma	I–II	6 (10.5%)
		III	7 (12.3%)
		IV	17 (29.8%)
	oligodendroglioma	III	2 (3.5%)
	metastasis		8 (14%)
	lymphoma		10 (17.5%)
other	abscess		3 (5.3%)
	toxoplasmosis		2 (3.5%)
	radionecrosis		1 (1.8%)
	no pathological result		1 (1.8%)
total			57 (100%)

in the final sample was not sufficient for further differentiation. The results are summarized in Table **3**.

Two patients had a first single seizure in the direct postoperative course. We observed two cases of postoperative infection (3.5%), one superficial wound infection and a meningitis. Both could be treated successfully with antibiotic medication.

An initial neurological deterioration occurred in five cases (9%) including three patients with increased hemiparesis (5.3%), two resolved after antiedematous treatment. One patient developed hemiparesis after biopsy of a right extensive precentral high grade glioma in whom postoperative CT revealed an increased focal edema. No hemorrhage was found. In another patient with temporal lobe biopsy, a visual-field defect occurred. In one patient a preoperative motoric dysphasia increased temporarily. No patient died during the immediate postoperative course.

Discussion

The precise histological diagnosis is essential for the further treatment of a patient. Therefore, it is necessary that whatever method of brain biopsy is used sampling of sufficient amount of representative tissue is achieved. Until now, the gold standard for stereotactic brain biopsy is frame-based stereotaxy. We retrospectively analyzed our series of 57 patients with supratentorial lesions which were biopsied using a frameless stereotactic system.

In 55 of 57 cases (96.5%) a definitive positive diagnosis was obtained. In one case histological examination described pathological findings for metastasis without further specification. In another case, no pathological tissue was found in the final examination after positive findings in the frozen section. The overall diagnostic yield in our series with frameless stereotaxy and intraoperative frozen section examination was 98%.

This diagnostic yield is comparable with the results of recent studies of frame-based (80% to 97% diagnostic yield) [20, 32, 34] and frameless stereotaxy (97 to 100% diagnostic yield) [4, 9, 14, 26].

In the postoperative course three cases of transient deterioration in the neurological status were observed, in two other cases a new neurological deficit remained (3.5%). Although previous studies often did not distinguish between transient and permanent neurological deficits, the morbidity rate ranged from 0.4% to 11% [2, 3, 5, 11, 21, 26].

The mean operation time of 92 min in our study is significantly longer than reported in other comparable studies [1, 26, 33]. This is mainly caused by our biopsy protocol in which an initial specimen is being examined by a neuropathologist for the likelihood of sufficient and pathological material. In case of ambiguous findings a second or third biopsy was performed. In the case of brain abscess, where no pathological confirmation during surgery was required, the mean operation time was 40 min.

Frame-based and frameless stereotaxy are not competing methods, but in selected cases both can be used with comparable security and diagnostic yield. In our opinion the indication for frameless stereotactic brain biopsy are mainly supratentorial lesions with a diameter of more than 10–15 mm. The advantages of frameless systems for this indication group that include a large amount of biopsy cases in general neurosurgery are the relative simple and time-sparing procedure and the intuitive possibilities of trajectory planning. Neuronavigation can be considered as a technique almost all neurosurgeons are familiar with. Frame-based sterotaxy is not available in all centres and often performed by subspecialized neurosurgeons. However, if high accuracy is demanded, frame-based systems offer clear advantages. The rigid geometry of the frame and the guidance apparatus is clearly more stable and better suited for deep seated biopsies of lesions located in the brain stem or the pineal region.

Regarding accuracy, especially the technical accuracy, both methods are comparable [18, 23, 27, 30]. However, overall clinical application accuracy, is lower in the frameless systems, due to the lack of satisfactory mechanical cannula guidance. A review of both techniques has been published by Raabe and co-workers [27]. Factors as image acquisition, modality (CT, MRI), and brain shift effect both frameless and frame-based methodology. One of the most crucial factors influencing accuracy of frameless stereotaxy is the registration technique, e.g. point-based with skin fiducials or fixed bone screws or surface-based methods [22].

It is possible to integrate functional data identifying eloquent brain areas (e.g. MEG and fMRI) into the three-dimensional data set [10, 19, 24] both in frame-based and frameless stereotaxy.

Conclusion

The results of our series demonstrate that frameless stereotactic systems can also be applied reliably for biopsy of supratentorial lesions larger than 15 mm.

Frameless stereotaxy in combination with intraoperative pathological confirmation is a safe and reliable method for stereotactic brain biopsy with a diagnostic yield comparable to frame-based stereotaxy.

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