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FRAME-BASED STEREOTACTIC LOCALIZATION OF BRAIN LESION FOR EXCISION

OKVIRNA STEREOTAKSIJSKA LOKALIZACIJA LEZIJE MOZGA U CILJU NJENE EKSCIZIJE

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ABSTRACT

Introduction: Till the end of the 1980s, frame-based stereotaxy was the standard method for accurately localizing small brain lesions by introducing catheters into the lesion or for determining the tumor volume in space. The objective of this study was to analyze the caracteristics of frame-based stereotactic localization of brain lesion for excision and to compare the results of frame-based stereotactic localization of brain lesion for excision with results of craniotomy without using stereotaxy.
Material and methods: This study analyzed the results of 100 surgically treated patients for brain lesion excision in the period of 2002-2006 at Department of neurosurgery University clinical center of Tuzla. There were 60 patients operated on by a craniotomy without using stereotaxy and 40 patients operated on by using frame-based stereotactic localization of brain lesion for excision. The Karnofsky Performance Score (KPS) was used to estimate the patient every day activity before and after surgery. Length of incision, size of craniotomy and duration of surgery were compared between two groups.
Result: An average age in patients operated on by using frame-based stereotactic tumor localization (Group A) was 49.5 (SD $\pm$13 years) and in patients operated on by craniotomy without using stereotactic localization (Group B) 53 years (SD $\pm$12 years). The mean length of skin incision in Group A was 7 cm (SD $\pm$5.5) and in Group B 14.5 cm (SD $\pm$4.7). The mean size of craniotomy in frame-based stereotactic localization for brain lesion removal was 10.7 cm^2 (SD $\pm$9.8), and in craniotomy without stereotaxy 18.5 cm^2 (SD $\pm$7.7). Duration of surgery in patients of Group A was 68 minutes (SD $\pm$43), and in Group B 125 minutes in average (SD $\pm$47). In the Group A there was no significant change in Karnofsky, but in the Group B there was drop.
Discussion and Conclusion: Frame-based stereotactic localization of brain lesion for excision gives advantages comparing craniotomy without using stereotaxy. Frame-based stereotaxy remains the gold standard for accurate targeting of smaller lesions.

Key words*:* Frame-based stereotaxy, brain lesion, excision

APSTRAKT

Uvod: Do kraja osamdesetih godina prošlog stoljeća, okvirna stereotaksija bila je standardna metoda za preciznu lokalizaciju malih lezija mozga uvođenjem katetera u leziju ili determiniranjem zapremine tumora u prostoru. Cilj ove studije bio je analizirati karakteristike okvirne stereotaksijske lokalizacije lezije mozga u svrhu njene ekscizije i uporediti njene rezultate sa rezultatima kraniotomije bez korištenja stereotaksije.
Materijal i metode: Studija je analizirala rezultate 100 hirurški liječenih pacijenata zbog ekscizije lezije mozga u periodu od 2002. do 2006. na Odjeljenju neurohirurgije Univerzitetskog kliničkog centra Tuzla. Šezdeset pacijenata operirano je kraniotomijom bez korištenja stereotaksije, a četrdeset pacijenata korištenjem okvirne stereotaksijske lokalizacije u cilju ekscizije lezije mozga. Karnofski skor korišten je u procjeni svakodnevne aktivnosti pacijenata prije i poslije operacije. Dužina incizije, veličina kraniotomije i trajanje operacije komparirane su između dvije grupe pacijenata.
Rezultati: Prosječna dob pacijenata operiranih korištenjem okvirne stereotaksijske lokalizacije lezije (Grupa A) bila je 49.5 (SD $\pm$13 godina), a u pacijenata operiranih kraniotomijom bez korištenja stereotaksijske lokalizacije

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(Grupa B) 53 godine (SD ±12 godina). Srednja dužina incizije u Grupi A bila je 7 cm (SD ±5.5), a u Grupi B 14.5 cm (SD ±4.7). Srednja veličina kraniotomije kod okvirne stereotaksijske lokalizacije bila je 10.7 cm^2 (SD ±9.8), dok je kod kraniotomije bez stereotaksije iznosila 18.5 cm^2 (SD ±7.7). Trajanje operacije u pacijenata Grupe A bilo je u prosjeku 68 minuta (SD ±43), a u Grupi B 125 minuta (SD ±47). U Grupi A nije bilo promjena u Karnofski skoru, dok je u Grupi B zapaženo sniženje.

Diskusija i Zaključak: Okvirna stereotaksijska lokalizacija lezije mozga u cilju njene ekscizije ima prednosti u poređenju sa kraniotomijom bez korištenja stereotaksije. Okvirna stereotaksija ostaje zlatni standard za precizno ciljanje manjih lezija.

Ključne riječi: Okvirna stereotaksija, lezija mozga, ekscizija

INTRODUCTION

Development of modern neurosurgical techniques has been closely related to advancements in the methods for localizing brain lesions[1-5]. Possibility to determine spatial relationships between lesions and intracranial anatomical landmarks and the development of atraumatic approaches have been crucial for reduced neurosurgical mortality and morbidity[6,7].

Until the end of the 1980s, frame-based stereotaxy was the standard method for accurately localizing small brain lesions by introducing catheters into the lesion[8-10] or for determining the tumor volume[11]. In frame-based stereotaxy, coordinate transformation of the selected target point between the image and the frame space is performed by use of a localization frame. Some of the stereotactic systems, such as Brown-Robert-Wells (BRW) and Cosman-Roberts-Wells (CRW) frames, use the rods of the localization frame to calculate a transformation matrix identical to the paired-point transformation method of frameless stereotaxy[12].

The aim of this study was to analyze the caracteristics of frame-based stereotactic localization of brain lesion for excision and to compare the results of frame-based stereotactic localization of brain lesion for excision with results of craniotomy without using stereotaxy.

PATIENTS AND METHODS

In the period of 2002-2006 of a database search, we identified 450 patients operated on for brain lesion at Department of neurosurgery University clinical center of Tuzla. The patients with the age between 21 and 75 years, both genders and with supratentorial brain lesion estimated on the base of CT or MR less than 5 cm in diameter of the lesion were included in this study. The study analyzed the results of 100 surgically treated patients for brain lesion excision in the same period. The patients with suspected meningeoma on CT or MR, infratentorial lesion and with the brain lesion larger than 5 cm in size were excluded. The patients were divided in two groups: Group A that included 40 patients operated on by using frame-based stereotactic localization and Group B that included 60 patients operated on without using stereotaxy. The surgical approach was chosen on the basis of the surgeon preference to do framed or not-framed craniotomy. The two groups did not differ significantly in patient age, duration of symptoms, sex ratio; initial Karnofski score; duration of symptoms and size of lesion (Table 1).

Table 1. Clinical characteristics of 100 patients
Tabela 1. *Kliničke karakteristike 100 pacijenata*

Characteristic	Group A (SD)	Group B (SD)	P (CI 95%)
Clinical data	49.5 yrs	53 yrs	
Age	(13)	(12)	
Sex M/F	12/28	19/41	
Duration of symptoms	45.5 days (48)	42 days (52)	0.6804
Diemeter of lesion	3.1 cm (2.1)	3.5 cm (1.9)	0.3826
KPS before	3 (7.5)	-	0.4728
surgery*	9 (22.5)	7 (11.5)	
100	8 (20)	10 (16.5)	
90	12 (30.0)	30 (50.0)	
80	2 (5.0)	2 (3.0)	
70	4 (10.0)	7 (11.5)	
60	2 (5.0)	4 (6.5)	
50			
40			

*There were no patients with Karnofsky score below 40.

Stereotactic procedure consisted of attachment of the Cosman-Roberts-Wells (CRW) frame before surgery and localization of the lesion to be resected via CT with contrast. Size of lesion was measured before surgery using CT or MR. Length of inci-

sion and size of craniotomy were measured during the surgery. Duration of surgery was estimated from the beginning of skin incision to the wound closure. Patient's outcome was estimated on the tenth postoperative day.

The Karnofsky Performance Score (KPS) was used to estimate the patient every day activity before and after surgery. Length of skin incision, size of craniotomy, size of brain lesion, duration of surgery and outcome were compared between two groups. Preoperative and postoperative imaging was obtained using the CT (Somatom plus, Siemens), and coordinate transformation of the selected target point between the image and the frame space was established using CRW stereotactic frame (Radionics, Burlington, MA). Stereotactic procedure had three phases: collecting basic tumor informations, planning of operating treatment and interactive procedure. Whenever possible, catheter direction was defined to avoid passing through the sulcus and blood vessels. The catheter direction was counted to minimize passing through an ependimal surface. All patients were operated on in general anesthesia. A microsurgical technique with the aid of the Karl-Zeiss microscope was used to remove the lesion. In all cases the lesion was removed completely. The patients were operated on by three neurosurgeons who participated in the study. The MR and CT were used to establish diagnosis of brain lesion, and for a control evaluation. All lesions underwent histopathological analysis.

Clinical data, duration of symptoms, size of lesion, length of skin incision, size of craniotomy, duration of surgery, complications and outcomes in two groups were compared using chi-square tests or t-tests, as appropriate. A probability value less than 0.05 was considered significant. Results for groups are presented as the means $\pm$ standard deviation. The data are computed by the MedCalc software (Broekstraat 52, 9030 Mariakerke, Belgium, http://www.medcalc.be).

RESULTS

According to neurological status a hemiparesis was the most frequent symptom and first sign of disease in both groups with 31 cases (77.5%) in Group A and 34 cases (56.5%) in Group B.

In 15 cases of Group A (37.5%) intracranial lesion was located in left hemisphere, and in 25 cases (62.5%) in right hemisphere. In 26 cases (43%) of Group B the lesion was located in left hemisphere and in 34 cases (57%) of right hemisphere (P = .449692). The most frequent localization in Group A was frontal lobe (52.5%), than parietal lobe (40%), thalamus and basal ganglia (22.5%), temporal lobe (15%), corpus callosum (7.5%), occipital lobe (5%) and intraventricular region (2.5%). In 42% of patients in this group the tumors bridged more than one lobe and there is an overlap in the summation. The most frequent localization in Group B was frontal and parietal lobes (41.5% respectively), than temporal lobe and thalamus/basal ganglia (31.5% respectively), occipital lobe (10%), corpus callosum (6.5%) and hipothalamus/supraselar region (1.5%) (95% CI 4.4-9.4, P= .4232). In this group there was also the tumors that bridged more than one lobe and the summation is not 100%. Right hemisphere was more involved by the tumors in Group A (62.5%) than in Group B (57%) (P = .449692). Frontal and parietal lobes were more involved in the group operated on by stereotactic localization (52.5% and 40% respectively) comparing to 41.5% respectively in the group operated on by free craniotomy. Of other regions of brain, more frequent were involved temporal lobe and thalamus/basal ganglia in Group B 31.5% respectively (P= .4232).

Clinical characteristics of 100 patients were shown in Table 1. Lesion size was estimated on the base of CT or MR and during surgery. In Group A diameter of the lesion was between 1 cm and 4 cm. In one case of this group there were two tumors that were removed. Diameter of the lesion in Group B was between 1 and 5 cm. A skin incision had linear or hors-shoe shape. The length of skin incision in Group A was between 2 and 15 cm. The length of incision in Group B was between 7 and 22 cm. The size of craniotomy in both groups was between 9 and 49 cm^2 but with an average significant difference (SD +7.7) (P= .0026). Duration of surgery in patients of Group A was between 20 and 150 minutes. Preparing for frame-based stereotactic localization for lesion removal has taken 60 minutes. Duration of surgery in Group B was between 60 and 210 minutes. The KPS has changed after surgery in both groups. In Group A, the average KPS increased from 75 before surgery to 76 after surgery. Of 8 patients in Group A who had the

KPS < 70, one patient died for a postoperative intracerebrale bleeding despite its emergency evacuation, and one patient died for lung complications. Mortality rate in Group A was 5%. In Group B the average KPS decreased from 70 before surgery to 57 after surgery with mortality rate of 8 cases (13%) (Table 2).

Table 2. Postoperative clinical characteristics of 100 patients
Tabela 2. *Postoperacijske kliničke karakteristike 100 pacijenata*

Characteristic	Group A (SD)	Group B (SD)	P (CI 95%)
Length of skin incision	7 cm (5.5)	14.5 cm (4.7)	< 0.0001
Size of craniotomy	10.7 cm^2 (9.8)	18.5 cm^2 (7.7)	0.0026
Duration of surgery	68 minutes (43)	125 minutes (47)	< 0.0001
Postoperative KPS	76	57	0.0002

According to histopathological analysis the most frequent lesion was glioblastoma multiforme (GBM) in both groups (Table 3). Causes of deterioration in patients operated on by frame-based stereotactic localization were intracerebral hematoma in one case (2.5%) and local edema of brain tissue in 4 cases (12.5%). Complications in patients operated on by without using stereotaxy were present in 16 cases (26.5%). The most frequent complication was postoperative bleeding in 7 cases (11.5%), local edema of brain tissue in 6 cases (10%) and local lesion of eloquent brain in 3 cases (5%) (95% CI 11.5-18.8, P = 0.4078) (Figure 1).

Table 3. Results of histopathological analysis of brain lesions
Tabela 3. *Rezultati patohistološke analize lezija mozga*

Type of lesion	Group A No. (%) of patients	Group B No. (%) of patients
Low-grade glioma	6 (15)	9 (15)
Anaplastic astrocytoma	7 (17.5)	13 (21.5)
GBM	14 (35)	23 (38.5)
Cavernous angioma	2 (5)	2 (3.5)
Metastasis	10 (25)	13 (21.5)
Colloid cyst	1 (2.5)	/
Total	40 (100)	60 (100)

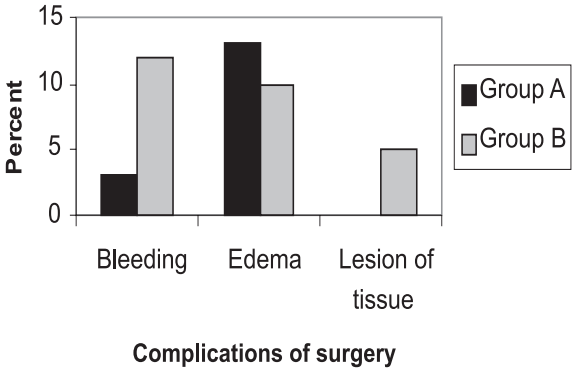

Figure 1. Causes of deterioration after surgery
Slika 1. *Uzrok deteriorijacije nakon operacijskog zahvata*

The most frequent neurological deterioration in this group was temporary deficit that continued to persist after surgery in 3 cases (5%).

DISCUSSION

The most number of publications about frame-based stereotactic systems analyzed results of stereotactic biopsy or functional neurosurgery, and reports about frame-based stereotactic localization for removal of intracranial tumors are rare [6, 8, 9, 12, 15, 25, 26, 27, 28]. Now days, results of stereotactic procedures and removal of intracranial tumor are mostly related to frameless stereotaxy[22, 29, 30]. During the frame-based stereotactic localization it was used a perpendicular direction of stereotactic probe in relation to the skin. The place of skin incision and craniotomy was planed on a way to avoid the probe direction through the eloquent zone or some of the vessels. With the aid of the probe direction it was possible to plane a small incision and small craniotomy. A tip of stereotactic probe was usually set in the middle of linear incision or in the center of horseshoe skin flap. On this way it was possible to achieve 7 cm of skin incision in stereotactic procedure. Length of skin incision in patients operated on without stereotaxy was double longer. Craniotomy estimated without stereotaxy was 10.7 cm^2 and double larger in size comparing to the frame-based stereotactic craniotomy (18.5 cm^2). Despite many reports about advantages of stereotactic localized craniotomy, we did not find similar studies that compared length of skin incision and size of craniotomy between the frame-based stereotactic craniotomy and craniotomy without stereotaxy.

With the aid of stereotactic probe direction, it was possible to approach the lesion on the shortest way and without wasting the time for searching the lesion. Duration of frame-based stereotactic surgery ("skin to skin") was 68 minutes comparing with surgery without stereotaxy that lasted 125 minutes. Deterioration of the KPS was noticed in patients operated on without stereotaxy from 70 before surgery to 57 after surgery. There are many reports about the results and complications of stereotactic procedures. Kaakaji et al, report that the most complications in their series happened within 6 hours after surgery, and longer observation did not showed postponed deterioration. The most frequent complication in their study was temporary deficit as a consequence of local brain edema or direct tissue trauma.

Intraoperative localization technique, including positioning of the craniotomy and the direction of preparation, is based on knowledge of characteristic bony landmarks, such as coronal suture, protuberantia occipitalis externa, etc., and neurosurgeon's skill and 3D knowledge. Identification of anatomic guiding structures during operation such as cranial nerves, vessels, and characteristic bony landmarks at the skull base, serves as points of spatial orientation. This anatomic localization method was the gold standard not only before CT and MR imaging but also after their introduction[13, 14].

Frame-based stereotactic localization techniques were developed based on a rigid coordinate system in which the target and a straight trajectory were determined based on the image information [15]. However, until recently microneurosurgeons were more comfortable with intraoperative anatomic identification than with stereotactic coordinates [16, 17, 18, 19, 20, 21]. Frame-based stereotaxy forced neurosurgeons to adapt their microsurgical techniques to the rigid stereotactic systems, which worked with high accuracy but reduced flexibility [22].

At our department, we prefer a debt of 3-5 mm among the axial stereotactic slices to show clearly a target and surrounding brain structure. A base of all stereotactic procedures is minimizing of probe direction near the critical vascular structures. Comparing the registration accuracy of frame-based and navigational systems, frame based calculations are in the range of the image resolution [14, 15, 23], and frameless calculation depends on the method of registration.

Raabe et al, analyse the most important factors that influence the decision on when to use frameless and when frame-based stereotaxy, investigating criteria such as application accuracy, image information and ergonomics [22]. With high quality images (1 mm slices thickness) and bone marker registration, frameless stereotaxy may achieve an application accuracy comparable to frame-based systems. Frame-based stereotaxy offers advantages over non-frame based craniotomy for lesions of 1-5 cm.

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