



The Impact of the Use of Neuronavigation Together with Intraoperative Ultrasonography In Minimally Invasive Intracranial Cavernous Hemangioma Surgery

ORIGINAL
INVESTIGATION

A. Fettah Tümtürk, Ahmet Küçük, Halil Ulutabanca, Ahmet Menkü, İ. Şamil Gergin, Şükrü Oral

ABSTRACT

Objective: To investigate the contribution of the use of neuronavigation together with intraoperative ultrasonography in the surgical treatment of cavernous hemangiomas to the decrease of mortality and morbidity.

Materials and Methods: A total of 73 cases with cavernous hemangiomas, operated on under the guidance of neuronavigation and intraoperative ultrasonography between June 2000 and September 2010 in the Neurosurgery Department of the University of Erciyes, were investigated retrospectively. The cases were evaluated from the point of neurological deterioration due to surgery.

Results: The lesions were mostly located supratentorially, especially in the temporal region. The most common complaint of supratentorially located lesions was epilepsy. Such findings and symptoms as bleeding, headache, and focal neurological deficits were observed mostly in the lesions of infratentorial region; 80 cavernous hemangiomas in 73 cases were removed in total. In 3 of the cases, a temporary increase in the neurological deficits was observed; however, in the late periods, no persistent morbidity or mortality due to surgery was observed.

Conclusion: By using neuronavigation together with intraoperative ultrasonography, the inconsistency between real location and the navigation image of the lesion resulting from the brain shift due to cerebrospinal fluid drainage can be restored; so, the morbidity and mortality can be decreased.

Keywords: Neuronavigation, intraoperative ultrasonography, cavernous hemangioma

INTRODUCTION

Cavernous hemangiomas (CHs), also known as cavernous malformations, cavernous angiomas, or cavernomas, are benign vascular lesions with a thin vessel wall, slow blood flow, and lack of muscle layer that consist of endothelial cells and can not be detected in angiography (1-3). Their incidence is 0.3-0.7% in the population, and they constitute 10%-20% of all vascular lesions (4, 5).

Cavernous hemangiomas are generally found at the supratentorial region (80%). Infratentorial (15%) or spinal (5%) locations are encountered less often (6, 7).

With regard to the incidence of CH, there is no difference between genders. It can appear at any age, from newborn age to the 9th decade of life. Its incidence is higher between the 3rd and 5th decades of life. The lesions generally present as single lesions, but they can also be multiple lesions. Moreover, in the literature, it has been reported that some cases have inherited CH from family members (8, 9).

Cavernous hemangiomas can be confused with gliomas, arteriovenous malformations, venous angiomas, thrombosed aneurysms, craniopharyngiomas, meningiomas, metastases, and inflammatory lesions in the differential diagnosis (8, 10).

Generally, arteries and veins are not seen in the angiography, but very tiny arterioles can sometimes be monitored. No pathological finding can be detected, due to low circulation flow rate and thrombus. On the other hand, large veins, capillaries, and neovascularization can sometimes be found (11, 12).

Magnetic resonance imaging (MRI) is the most effective imaging technique for the diagnosis of CHs, which appear as areas of mixed signal intensity with a surrounding hypointense rim in T1W MRI. Generally, contrast is not enhanced, but sometimes, mild contrast enhancement can be observed. In bleeding cases, the appearance of popcorn is typical (1). A hemosiderin-stained gliotic layer, associated with chronic slight bleedings, surrounds the lesion (9). In computed tomography (CT), CHs are generally seen as iso/hypodense. In contrast-enhanced CT, they involve contrast slightly, but when they are hemorrhagic or calcific, they are seen as hyperdense (9, 11).

Department of Neurosurgery,
Erciyes University Faculty of
Medicine, Kayseri, Turkey

Submitted
19.11.2013

Accepted
14.01.2014

Correspondance

A. Fettah Tümtürk MD,
Department of Neurosurgery,
Erciyes University Faculty of
Medicine, Kayseri, Turkey
Phone: +90 352 207 66 66
e.mail:
fettahtumturk@yahoo.com

©Copyright 2014
by Erciyes University School of
Medicine - Available online at
www.erciyesmedj.com

Central nervous system CHs typically present with epilepsy, bleeding, or a mass lesion (13). Moreover, they can lead to headache and focal neurological deficits, depending on the complications, such as their size, location, and bleeding (9).

Cavernous hemangiomas are often small in size and are located in regions that are difficult to reach. In addition to preoperative identification of the ideal surgical approach, the possibility of intraoperative administration of surgical plan is critical for a successful operation (14).

MATERIALS and METHODS

A total of 73 patients, who were operated on with neuronavigation and intraoperative ultrasonography (IOUS) in the Department of Neurosurgery at the Faculty of Medicine of Erciyes University between June 2000 and September 2010, were evaluated retrospectively.

Surgical Procedure

The cases were assessed with regard to neurological damage associated with surgery and excision of the lesion. Neuronavigation (Vector Vision 2; Brain Lab, Munich, Germany) and 7 MHz probe IOUS (Toshiba; Tosbee, Tokyo, Japan) were used in the study. In order to be able to perform the optimum craniotomy for the lesion, to identify the proper angles for reaching the lesion, and to carry out minimally invasive surgery, skin markers were attached in all cases. Then, cranial MRI was performed, and images were transferred to the data processing unit of neuronavigation. The head was fixed with a Mayfield skull-pin head holder (Mayfield headholder; OMI surgical products, Cincinnati, OH, USA), and registration was performed using skin markers. During the operation, IOUS evaluation was repeated many times. Navigation data were updated with real-time images that were obtained.

The brain shift, which resulted from resection and cerebrospinal fluid drainage and led to inconsistency between the location of the lesion and the image, was measured to be between 1.7 mm and 6 mm. Then, it was corrected for a safer surgical process.

Statistical Analysis

The data obtained were analyzed using descriptive statistical techniques.

RESULTS

Sixty-eight of 73 patients underwent surgery for a single intracranial CH, and 5 patients were operated on for multiple intracranial CHs (2 patients with 3 CHs, 3 patients with 2 CHs; 80 intracranial CHs in total).

Of the intracranial CH cases, 33 (median 36.2, minimum 11, maximum 74 years,) were male and 40 (median 34.9, minimum 5, maximum 68 years) were female. Supratentorial localization was observed to be more often in the cases, and CHs were located in the temporal, parietal, and frontal regions, considering their frequencies. The distribution of the lesions according to their localization is shown in Table 1.

The most common complaint for the lesions with supratentorial localization was epilepsy in 41 of 64 cases (64%). On the other hand, for lesions with infratentorial localization, it was headache in 6 of

Table 1. Distribution of lesions according to their localization

Location of lesion (Supratentorial)	n	%
Temporal	22	27.5
Parietal	17	21.2
Frontal	10	12.5
Occipital	7	8.7
Hippocampal	4	5
Insula	3	3.7
Intraventricular	1	1.3
Total	64	80
Location of lesion (Infratentorial)	n	%
Cerebellum	11	13.7
Brain stem	5	6.3
Total	16	20

16 cases (37.5%) and focal neurological deficit in 4 cases (25%). Bleeding was observed in 14 lesions with supratentorial localization (21.8%) and in 8 lesions with infratentorial localization (50%). In the preoperative neurological evaluation, in a patient with a bleeding CH located in the pontomesencephalon, in addition to 6th and 9th cranial nerve palsies, hemiparesis, and ataxia, an increase in existing ataxia and partial healing in the 6th and 9th cranial nerve palsies were observed in the early postoperative period. Cranial nerve palsies were completely improved in the follow-up examination performed 1 month later. In the first postoperative year, the ataxia of the patient was at the same level as in the preoperative period. Bleeding was detected in 2 cases having a lesion located in the brain stem and in 6 patients having a lesion with cerebellar localization. Of the cases with supratentorial localization, a postoperative increase in motor dysphasia was observed in a patient having a CH with left insular localization and motor dysphasia, but it got well at late follow-ups. In the patient with left precentral localization, convulsion and 3/5 hemiparesis were detected on the right side in the preoperative neurological evaluation. In the hemiparesis of this case, which increased in the early postoperative period, an apparent recovery was seen during the time of hospitalization. It healed completely in the 3rd postoperative month. In other cases with focal deficits, neurological deficit secondary to surgery was not found. Moreover, permanent morbidity associated with surgery was not detected, and there was no mortality at the late follow-ups. The distribution of symptoms according to localization is presented in Table 2.

DISCUSSION

Magnetic resonance imaging is the most sensitive and specific non-invasive diagnostic method for the diagnosis of CHs, which are benign vascular lesions that can not be monitored in angiography. The differential diagnosis includes bleeding neoplasms, such as brain metastasis; meningiomas; low- and even high-grade glial tumors; inflammatory lesions, such as cysticercosis and chronic granuloma; arteriovenous malformations; venous angiomas; thrombosed aneurysms, craniopharyngiomas; and rare intracranial lesions, like lipomas (8, 10).

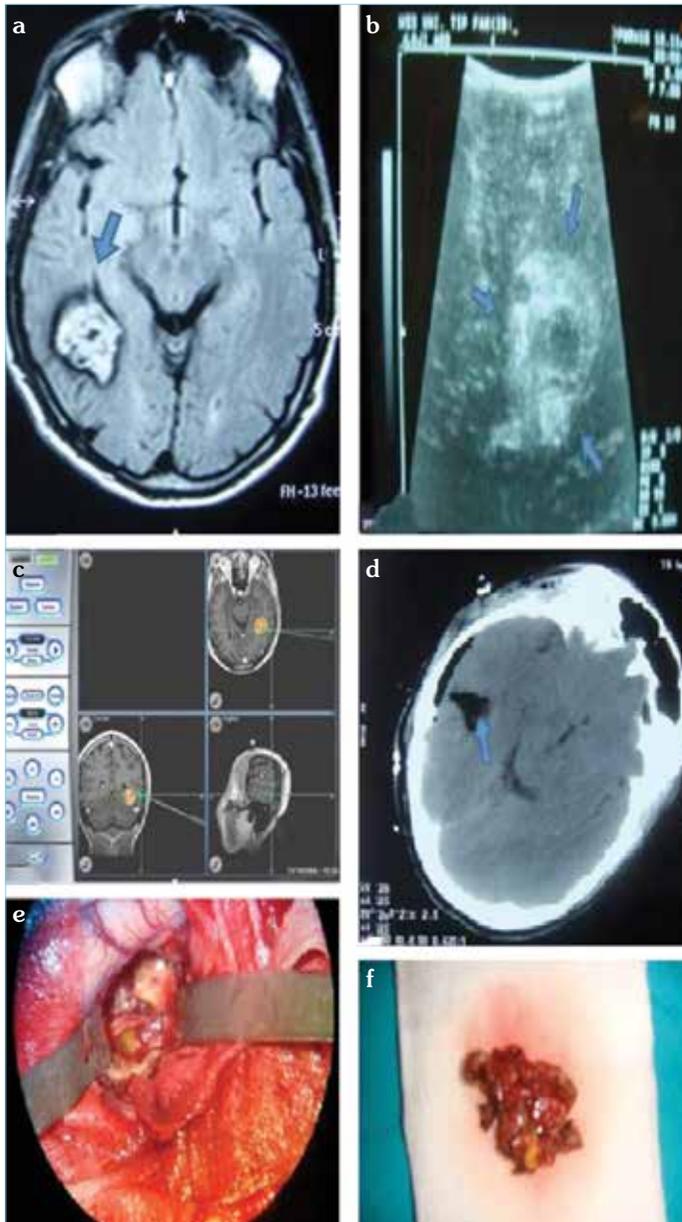


Figure 1. a-f. In the T1A axial MRI, (a) a lesion with right occipital localization, which has a surrounding hypointense rim, including hypointense areas at its center, and is consistent with bleeding CH, is observed. In the intraoperative IOUS image (b) and navigation image (c) and in the postoperative axial CT (d), it is seen that the lesion was totally excised. Intraoperative microscope image (e) and totally excised lesion (f) are observed.

Typical clinical symptoms of CH are epilepsy (23%-81%), bleeding (7%-70%), focal neurological deficit (5%-62%), headache, and increased intracranial pressure (8,13). The surgical treatment of CH aims to prevent bleeding, to remove hematomas, to reduce mass effects in bleeding cases, and to provide seizure control in epileptic cases (15). Recently, elective surgery has been recommended for reducing the possible risk of bleeding and neurological damage in young patients (8). Most CHs are supratentorially located. Epilepsy that occurs in association with epileptogenic activity of blood destruction products around the lesion is the most common clinical symptom in CH cases. In the surgical treatment of epileptic seizures caused by CH, excision of the lesion is generally considered to ensure seizure control in most patients. It is usually agreed that not only the malformation but also the surrounding hemosiderin-loaded gliotic area must be removed in order to get the seizure under control in supratentorial lesions (8, 13).

The main goal of surgical treatment for CHs of the brain stem is to remove the lesion totally and not to cause additional neurological damage. It is unnecessary to attempt to remove the gliotic tissue and hemosiderin ring around the cavity in cases with CHs of the brain stem, and this attempt is contraindicated, due to possible additional damage. There is a consensus on the time of surgery. Many authorities suggest that surgery be performed a few days or weeks after bleeding (in the subacute period), when the patient is stable (16).

In the literature, the rate of bleeding CHs per year is reported to be approximately 0.25% and 1.3% (17). Some authors pointed out that the possibility of rebleeding was high in patients having a history of bleeding, and they reported the rate of rebleeding as 30%/person/year and 21%/year/lesion. Moreover, rebleeding events can lead to serious neurological deficits (16). The rate of bleeding was found to be significantly higher in female patients having lesions of the brain stem (8, 13).

Especially in the surgical treatment of small CHs located in regions that are difficult to reach, sensitive intraoperative application of the surgical plan is critical for a successful operation, as well as identification of the ideal surgical approach (14).

Neuronavigation has a very important place in the surgery of lesions that are involved in complicated anatomic structures having critical importance, such as the skull base, or that are located in functionally active regions. Particularly in small and deeply located lesions, it helps to plan the incision, to identify the proper place for the craniotomy and the size of the craniotomy flap, to determine the ideal entry angles, to designate the critical anatomic structures,

Table 2. Distribution of symptoms according to localization.

Symptom and findings	Supratentorial (64-80%)		Infratentorial (16-20%)		Total (80)	
	n	%	n	%	n	%
Epilepsy	41	64	-	0	41	51.2
Bleeding	14	21.8	8	50	22	27.5
Headache	11	17.1	6	37.5	17	21.2
Focal deficit	7	10.9	4	25	11	13.7

and to protect these structures by establishing anatomical dominance. This contributes to a safer surgical procedure, resulting in minimum neural trauma, total resection, and minimum morbidity and mortality (8, 18-20).

The most important disadvantage of neuronavigation is the inconsistency with preoperative navigation images, which results from replacing the lesion and critical anatomic structures associated with brain shift that occurs due to intraoperative tumor resection or cerebrospinal fluid drainage. This creates a need for updating the preoperative image with the intraoperative image (18, 21).

In today's neurosurgery practice, devices that provide real-time localization of the lesion, such as intraoperative CT, intraoperative MRI, and neuronavigation, are used in order to decrease postoperative morbidity and mortality in cases with lesions located in sensitive areas and deep brain regions. Among these devices, IOUS is a method that is practically and technically reliable and that can provide real-time images, independent of size, in the localization of CHs and in the detection of deeply located lesions. Compared to other techniques performed for intraoperative imaging of the lesion, it is cheaper, and it can help to control the resection border of the lesion and to detect coexisting deep venous anomalies (18, 22).

IOUS is an alternative technique that is mobile, noninvasive, rapid, and cheaper than intraoperative MRI. With regard to tumor localization, features, and its relationship with critical anatomical points, it provides almost real-time and high-quality images. Furthermore, it helps to control the width of the resection and to update neuronavigation data rapidly. This method gives real-time data, so it ensures objective control of the surgical process.

The time needed for obtaining ultrasonographic images is shorter than that needed for intraoperative MRI. Intraoperative ultrasound can be repeated without interrupting the work-flow during the operation (21, 23).

CONCLUSION

Wide knowledge and experience are primarily essential for surgical success of CHs. Moreover, safer and more reliable resections can be performed by correcting brain shift, which results from cerebrospinal fluid drainage and which leads to the inconsistency between the real location and the navigation image of the lesion, through the use of neuronavigation, together with IOUS. Thus, postoperative morbidity and mortality can be reduced.

Informed Consent: Written informed consent was already obtained from patients who participated in this study.

Peer-review: Externally peer-reviewed.

Authors' Contributions: Conceived and designed the experiments or case: AFT, AM. Performed the experiments or case: AFT, AK, HU, AM. Analyzed the data: AFT, AM, İŞG, ŞO. Wrote the paper: AFT. All authors have read and approved the final manuscript.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study has received no financial support.

REFERENCES

1. Rigamonti D, Drayer BP, Johnson PC, Hadley MN, Zabramski J, Spetzler RF. The MRI appearance of cavernous malformations (angiomas). *J Neurosurg* 1987; 67(4): 518-24. [\[CrossRef\]](#)
2. Hegde AN, Mohan S, Lim CC. CNS cavernous haemangioma: "pop-corn" in the brain and spinal cord. *Clin Radiol* 2012; 67(4): 380-8. [\[CrossRef\]](#)
3. Little JR, Awad IA, Jones SC, Ebrahim ZY. Vascular pressures and cortical blood flow in cavernous haemangioma of the brain. *J Neurosurg* 1990; 73(4): 555-9. [\[CrossRef\]](#)
4. Moriarty JL, Wetzel M, Clatterbuck RE, Javedan S, Sheppard JM, Hoenig- Rigamonti K, et al. The natural history of cavernous malformations: a prospective study of 68 patients. *Neurosurgery* 1999; 44(6): 1166-73. [\[CrossRef\]](#)
5. Porter RW, Detwiler PW, Spetzler RF, Lawton MT, Baskin JJ, Derksen PT, et al. Cavernous malformations of the brain stem: experience with 100 patients. *J Neurosurg* 1999; 90(1): 50-8. [\[CrossRef\]](#)
6. D'Angelo VA, De Bonis C, Amoroso R, Cali A, D'Agruma L, Guarnieri V, et al. Supratentorial cerebral cavernous malformations: clinical, surgical and genetic involvement. *Neurosurg Focus*. 2006; 21(1): e9. [\[CrossRef\]](#)
7. Hassler W, Zentner J, Wilhelm H. Cavernous angiomas of the anterior visual pathways. *J Clin Neuroophthalmol* 1989; 9(3): 160-4.
8. Bertalanffy H, Benes L, Miyazawa T, Alberti O, Siegel AM, Sure U. Cerebral cavernomas in the adult. Review of the literature and analysis of 72 surgically treated patients. *Neurosurg Rev* 2002; 25(1-2): 1-53. [\[CrossRef\]](#)
9. El-Koussy M, Stepper F, Spreng A, Lukes A, Gralla J, Brekenfeld C, et al. Incidence, clinical presentation and imaging findings of cavernous malformations of the CNS. A twenty-year experience. *Swiss Med Wkly* 2011; 141(13): w13172.
10. Liu JK, Lu Y, Raslan AM, Gultekin SH, Delashaw JB Jr. Cavernous malformations of the optic pathway and hypothalamus: analysis of 65 cases in the literature. *Neurosurg Focus* 2010; 29(3): e17. [\[CrossRef\]](#)
11. Mariere JN, Awad IA. Intracranial cavernous malformations: Lesion behavior and management strategies. *Neurosurgery* 1995; 37(4): 591-605. [\[CrossRef\]](#)
12. Servo A, Porras M, Raininko R. Diagnosis of cavernous haemangiomas by computed tomography and angiography. *Acta Neurochir (Wien)* 1984; 71(3-4): 273-82. [\[CrossRef\]](#)
13. Churchyard A, Khangure M, Grainger K. Cerebral cavernous angioma: a potentially benign condition? Successful treatment in 16 cases. *J Neurol Neurosurg Psychiatry* 1992; 55(11): 1040-5. [\[CrossRef\]](#)
14. Stadie AT, Reisch R, Kockro RA, Fischer G, Schwandt E, Boor S, et al. Minimally invasive cerebral cavernoma surgery using keyhole approaches - solutions for technique-related limitations. *Minim Invasive Neurosurg* 2009; 52(1): 9-16. [\[CrossRef\]](#)
15. Gralla J, Gansland O, Kober H, Buchfelder M, Fahlbusch R, Nimsky C. Image-guided removal of supratentorial cavernomas in critical brain areas: application of neuronavigation and intraoperative magnetic resonance imaging. *Minim Invasive Neurosurg* 2003; 46(2): 72-7. [\[CrossRef\]](#)
16. Sandalcioğlu IE, Wiedemayer H, Secer S, Asgari S, Stolke D. Surgical removal of brain stem cavernous considerations, and results malformations: surgical indications, technical considerations, and results. *J Neurol Neurosurg Psychiatry* 2002; 72(3): 351-5. [\[CrossRef\]](#)
17. Moran NF, Fish DR, Kitchen N, Shorvon S, Kendall BE, Stevens JM. Supratentorial cavernous haemangiomas and epilepsy: a review of the literature and case series. *J Neurol Neurosurg Psychiatry* 1999; 66(5): 561-8. [\[CrossRef\]](#)

18. Kurtsoy A, Menku A, Tucer B, Oktem IS, Akdemir H. Neuronavigation in skull base tumors. *Minim Invasive Neurosurg* 2005; 48(1): 7-12. [\[CrossRef\]](#)
19. Germano IM, Villalobos H, Silvers A, Post KD. Postclinical use of the digitizer for intracranial neuronavigation. *Neurosurgery* 1999; 45(2): 261-70. [\[CrossRef\]](#)
20. Wadley J, Dorward N, Kitchen N, Thomas D. Pre-operative planning and intra-operative guidance in modern neurosurgery: a review of 300 cases. *Ann R Coll Surg Engl* 1999; 81(4): 217-25.
21. Rasmussen IA Jr, Lindseth F, Rygh OM, Berntsen EM, Selbekk T, Xu J, et al. Functional neuronavigation combined with intra-operative 3D ultrasound: Initial experiences during surgical resections close to eloquent brain areas and future directions in automatic brain shift compensation of preoperative data. *Acta Neurochir (Wien)* 2007; 149(4): 365-78. [\[CrossRef\]](#)
22. Woydt M, Krone A, Soerensen N, Roosen K. Ultrasound-guided neuronavigation of deep-seated cavernous haemangiomas: clinical results and navigation techniques. *Br J Neurosurg* 2001; 15(6): 485-95. [\[CrossRef\]](#)
23. Gerganov VM, Samii A, Giordano M, Samii M, Fahlbusch R. Two-dimensional high-end ultrasound imaging compared to intraoperative MRI during resection of low-grade gliomas. *J Clin Neurosci* 2011; 18(5): 669-73. [\[CrossRef\]](#)