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RADICALITY OF LATERAL VENTRICULAR NEOPLASMS REMOVAL AND RISK FACTORS OF POSTOPERATIVE HEMORRHAGIC COMPLICATIONS

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Introduction. Lateral ventricular neoplasms (tumors, vascular neoplasms, cysts) are rare and according to different sources comprise between 0.64 and 3.5 % of all brain tumors. Due to relatively slow growth, tumors can reach significant size before patient develops neurological symptoms. Surgery is the main method of treatment of lateral ventricular neoplasms, and in many cases radical removal can be achieved. The main complications after surgery are hydrocephalus and hemorrhages. The later frequently lead to escalation of neurological symptoms and sometimes require repeat surgical intervention. The success of intraventricular surgery consists of reasonable radicality and absence of complications.

Aims. To evaluate the radicality and safety of lateral ventricular tumor removal through traditional approaches – transcallosal and transcortical – using arterial spin labeling (ASL perfusion) and to analyze the risk of hemorrhagic complications in the early postoperative period in the context of tumor location and blood supply.

Materials and methods. At the N.N. Burdenko National Medical Research Center of Neurosurgery (2017–2019) 48 patients with space-occupying lesions of the lateral ventricles were examined and treated with surgery. All patients were examined using the same MRI protocol before and after surgery: T1-weighted, T1-weighed contrast-enhanced, 3D SPGR, T2-weighted, T2-FLAIR, DWI, T2-FLAIR CUBE, SWAN, ASL perfusion. In 28 (58 %) cases, transcortical approach was used (through the frontal lobe in 24 cases, through the upper temporal lobe in 2 cases, through the parietal lobe in 2 cases); transcallosal approach was used in 16 (33 %) cases; combination approach (for advanced tumors of the lateral ventricles) was used in 3 (6 %) cases; supracerebellar infratentorial approach was used in 1 (2 %) case. Radicality of lateral ventricular tumor removal and risk factors for postoperative hemorrhagic complications using different approaches were evaluated based on the following parameters: tumor volume and location, sex, blood flow characteristics, presence of hydrocephalus.

Results. In the compared groups I and II, similar rates of radical tumor removal were observed: 63 % for transcortical approach and 71 % for transcallosal approach. Hematomas in the tumor bed were more frequently observed in patients operated through transcortical approach (64 % vs. 31 % in transcallosal) without statistical significance. Generally, there were no statistically significant differences between surgical treatment results in groups I and II (p >0.05); this conclusion was confirmed in pseudo-randomized patient subgroups selected through propensity score matching. Analysis of the association between hematoma in the postoperative period and baseline blood flow level showed that in the group with such hematomas mean tumor blood flow prior to surgery was almost twice as high as in the group without hemorrhagic complications after resection (80.6 vs. 49.4 ml/100 g/min, respectively).

The following postoperative parameters are statistically significant for development of hematoma in the tumor bed: presence of hydrocephalus, Evans index in the early postoperative period.

Conclusions. Correct and adequate choice of surgical approach considering anatomical location and advancement of the tumor, presence of hydrocephalus and surgeon's preferences ensures high radicality of removal. Factors affecting the risk of hemorrhagic complications in the early postoperative period should be taken into account: sex, presence of hydrocephalus, neoplasm location and blood flow level.

Keywords: lateral ventricular neoplasms, postoperative hemorrhagic complications, transcortical approach, transcallosal approach, hydrocephalus, ASL perfusion

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INTRODUCTION

Lateral ventricular (LV) neoplasms – tumors, vascular neoplasms, cysts – are rare. According to different sources they comprise between 0.64 and 3.5 % of all brain tumors [1]. LV tumors can be classified into the following categories:

- primary growing from the pellucid septum, LV plexuses and ependyma or the lateral walls (subependymal zone);
- secondary growing into the ventricles from the cerebral matter.

Secondary tumors are classified according to their anatomical source (thalamus, corpus collosum, caudate nucleus, etc.). However, if the larger part of such tumor (approximately 2/3 of the volume) is located in the LV projection, surgical techniques for primary LV neoplasms can be applied [2, 3].

Due to relatively slow growth, LV tumors can reach significant size before patient develops neurological symptoms. Difficulty of their removal is a consequence of their large size (especially when they occupy almost all areas of the LVs). Depending on the size and location of LV tumors and presence of hydrocephalus, several different surgical approaches are used allowing for minimal retraction of brain tissue and preservation of normal anatomy. LV neoplasms can be accessed through transcallosal, transcortical approaches, in some cases through supracerebellar, subfrontal, pterional approaches.

The main complications after surgical treatment of LV neoplasms are hemorrhagic events and hydrocephalus. Frequently, hemorrhagic complication leads to escalation of neurological symptoms after surgery and sometimes require repeat surgical intervention. Therefore, the success of intraventricular surgery consists of achievement of reasonable radicality without complications.

The study aims are to evaluate the radicality and safety of LV tumor removal through traditional approaches – transcallosal and transcortical – using arterial spin labeling (ASL perfusion), and to analyze the risk of hemorrhagic complications in the early postoperative period in the context of tumor location and blood supply.

Table 1. *Symptoms prior to surgical treatment in patients (n = 48) with space-occupying lesions of the lateral ventricles*

Symptoms	Manifestations	Number of patients, *n* (%)
Neurological	Paresis	4 (8)
	Epileptic seizures	2 (4)
	Speech disorders	0 (0)
	Memory loss	22 (46)
Ophthalmological	Oculomotor disorders	0 (0)
	Visual field loss	1 (2)
	Changes in ocular fundus: venous stasis venous stasis with hemorrhage normal venous hyperemia	 20 (42) 6 (13) 16 (33) 6 (13)

MATERIALS AND METHODS

At the N.N. Burdenko National Medical Research Center of Neurosurgery between 2017 and 2019 48 patients with space-occupying lesions of the lateral ventricles were examined and treated with surgery. Mean patient age was 43.5 ± 15 years.

The following inclusion criteria were applied:

- age above 18 years;
- space-occupying LV lesion without previous surgical treatment;
- magnetic resonance imaging (MRI) performed according to a specific protocol before and after surgery (in the span of 48 hours).

Table 1 presents neurological and ophthalmological symptoms in patients with space-occupying LV lesions prior to surgical treatment.

In 26 (55 %) patients, symptoms of intracranial hypertension were found. Asymptomatic disease progression was not observed. Memory loss is a relatively frequent manifestation of intraventricular tumors. Before and after surgery all patients were examined by a neuropsychologist. Memory evaluation was performed as part of a complex neuropsychological approach to analysis of mental activity formulated by A.R. Luria and included: orientation in place, time, personal situation; memory for current events; testing of auditory-verbal and visual memory [4].

MRI protocol before and after surgery included the following modes: T1-weighted, T1-weighed contrast-enhanced, 3D SPGR, T2-weighted, T2-FLAIR, DWI, T2-FLAIR CUBE, SWAN, ASL perfusion.

Maps of cerebral blood flow were obtained through analysis of data from 3D pseudo-continuous arterial spin labeling (pCASL) which was performed with the following parameters: 3D FSE, 8-arm spiral scan with whole brain capture and slice thickness 4 mm; FOV = 240 × 240 mm; reconstruction matrix 128 × 128, ZIP 512; TR 4717 ms; TE 9.8 ms; NEX = 3; post label delay (PLD) 1525 ms; pixel bandwidth 976.6 Hz/pixel. Scan time was 4 min 30 s.

Data analysis was performed using READYView (GE Healthcare) software. For measurement of blood flow in the tumor, a region of interest (ROI) was selected with an area of 20 ± 10 mm^2 in the zone with the highest cerebral blood flow (CBF) which was identified though color blood flow maps. In the selected area, mean value of tumor blood flow (TBF) was calculated. For elimination of individual blood flow differences between the patients, TBF was normalized (nTBF) to blood flow in the intact white matter of the semioval center of the contralateral hemisphere. In this zone, ROI of the same area as in the tumor (20 ± 10 mm^2) was selected. Normalized value was calculated by division of TBF by blood flow in the semioval center: nTBF = max TBF/CBF of intact white matter in the semioval center of the contralateral hemisphere.

In all cases, blood flow maps were juxtaposed with anatomical T2-weighted, T2-FLAIR, T1-weighted images after intravenous contrast agent administration. Additionally, co-registration software NeuroRegistration (GE Healthcare) was used.

Tumor volume was measured using semiautomatic segmentation in AW Server (Ver. 4.2, GE Medical Systems) software platform in T2-FLAIR CUBE and FSPGR modes after IV contrast agent administration.

According to location of the space-filling lesion in LV projection, all patients were divided into 3 groups: with posterior location – 7, with middle location – 14, with anterior location – 27 cases. Tumor volume varied between 1.24 and 112.0 (median 18.9) cm^3.

Estimation of preoperative tumor volume involved 3 grades: large (>39 cm^3), intermediate (10–39 cm^3), small (<10 cm^3). Per location on either side of the brain, the following types were observed: bilateral – in 7 (14.6 %), left side – in 19 (39.6 %), right side – in 22 (45.8 %) patients.

The following anatomical relations between the space-occupying lesion and surrounding structures were observed: in 4 cases, pathological lesion advanced into the corpus callosum, in 2 cases into the thalamus, in 2 cases into the caudate nucleus head, in 2 cases into the caudate nucleus body.

In 26 (55 %) patients, hydrocephalus was diagnosed.

Patients were operated on through transcortical approach in 28 (58 %) cases (through the frontal lobe – 24, through the upper temporal lobe – 2, through the parietal lobe – 2), through transcallosal in 16 (33 %) cases, through combination approach (for advanced LV tumors) in 3 (6 %) cases, through supracerebellar infratentorial in 1 (2 %) case.

The approach was selected after detailed study of MRI data taking into account tumor location and volume, hydrocephalus grade. The primary goal was to remove all tumor parts under visual control with minimal brain injury (Table 2). Table 3 presents the decision-making algorithm for selection of approach depending on tumor location, advancement and size proposed by V.A. D'Angelo et al. [5].

The most frequent approaches to LV tumor removal were transcallosal ($n = 16$) and transcortical ($n = 28$), so we analyzed the results and risk factors of surgical treatment

Table 2. *Tactics for selection of surgical approach associated with tumor growth in removal of lateral ventricular tumors*

Structure	Tumor location	Approach
Anterior horn and anterior parts of the body	Intraventricular	Frontal transcallosal
	Transependymal superolateral	Middle frontal gyrus
	Transependymal superomedial	Frontal transcallosal
Temporal horn	Intraventricular, transependymal lateral from the dominant side	Middle/inferior temporal gyrus
	Transependymal lateral and/or frontal on the nondominant side	Frontal or expanded lobectomy
	Transependymal posterior or in the trigone area	Through the occipitotemporal gyrus

Table 3. *Selection of surgical approach for removal of tumors in the trigone and posterior parts of the lateral ventricles*

Approaches			
Associated with tumor development		**Associated with tumor size**	
tumor location	**approach**	**tumor size**	**approach**
Intraventricular	Superior parietal lobule, through the corpus callosum splenium	Small/medium with medial location	Superior parietal lobule, posterior transcallosal, through the corpus callosum splenium
Transependymal superior	Posterior transcallosal/superior parietal lobule	Small/medium with lateral location	Transtemporal/superior parietal lobule
Transependymal median	Posterior transcallosal/superior parietal lobule	Large without visual field loss	Superior parietal lobule/through the corpus callosum splenium
Transependymal lateral	Middle temporal gyrus	Large with visual field loss	Superior parietal lobule/through the corpus callosum splenium/occipital transcortical

in patient groups operated on through these traditional approaches [5].

To test hypotheses on the differences between results of surgical treatment using different surgical approaches, we used pseudo-randomization technique: patient selection through propensity score matching (PSM) [6]. This method allows to select subgroups with the same number of patients and relatively identical distribution of the main characteristics (potentially affecting surgery radicality and complication risk) from 2 groups. In 2 such pseudo-randomized subgroups, hypotheses on the differences can be tested with high reliability. In our study, PSM was used to form 2 pseudo-randomized subgroups with 13 patients each from the patients of groups I and II. Selection was done on the basis of the Evans index, sex, nTBF level and tumor location in the posterior right LV horn.

Multidimensional analysis of risk factors for postoperative hematomas in the tumor bed in the early postoperative period was performed using binary logistic regression model. Presence or absence of a hematoma were used as binary outcomes.

Statistical analysis of the data was performed using R programming language (www.r-project.org, version 3.6.3) in integrated development environment RStudio Server (version 1.3.1056). The scenario of statistical analysis is written as code for calculation automation and repeatability.

Statistical significance of differences in distributions of categorical variables was evaluated using Pearson's χ^2 test and Fisher's exact test. Differences in numerical values were evaluated using Student's t-distribution (for normally distributed random values) or Mann–Whitney U test (if hypothesis of normal distribution was disproven).

Results of hypothesis testing were considered statistically significant at significance level $p < 0.05$.

Analysis of tumor removal radicality using different approaches showed that through transcortical approaches tumors of large volume and size were removed with more cases of hydrocephalus which is the main difference between the 2 patient groups.

Baseline preoperative characteristics of the patients who underwent surgery through transcallosal (group I) and transcortical (group II) approaches are presented in Table 4.

Data on blood flow in the regions of interest for surgical intervention are presented in Table 5.

Separately the results of radicality and development of hemorrhagic complications in 2 similar subgroups of patients who were operated on through transcallosal ($n = 13$) and through frontal transcortical ($n = 13$) approaches were analyzed. Baseline characteristics of the subgroups selected using PSM are presented in Table 6.

Table 6 shows that selection using PSM allowed to balance out baseline characteristics of the compared subgroups, however, baseline principal differences in tumor size were not leveled out.

Blood flow characteristics in the tumor and other regions of interest in the similar subgroups selected using PSM are presented in Table 7. In these subgroups, there were no significant differences in blood flow parameters in the studied regions ($p > 0.05$).

Table 4. *Baseline preoperative characteristics of the patients who underwent surgery through transcallosal (group I) and transcortical (group II) approaches*

Parameter	Group		P-value
	I (n = 16)	II (n = 28)	
Tumor volume, n (%): large medium small	 3 (19) 2 (12) 11 (69)	 11 (39.3) 11 (39.3) 6 (21.4)	0.01
Tumor volume (T2-weighed MRI), cm^3 (median [quantiles])	3.8 [2.6; 15.7]	34.0 [15.4; 54.2]	0.003
Hydrocephalus, n (%)	6 (38)	19 (68)	0.06
Evans index prior to surgery, median [quantiles]	0.29 [0.27; 0.32]	0.38 [0.27; 0.41]	0.04

***Note.** MRI – magnetic resonance imaging.*

Table 5. *Preoperative blood flow characteristics (ASL perfusion) in patients who underwent surgery through transcallosal (group I) and transcortical (group II) approaches*

Blood flow characteristic, ml/100 g/min (median [quantiles])	Group		P-value
	I (n = 16)	II (n = 28)	
TBF	49.9 [32.5; 91.4]	72.2 [45.4; 114.8]	0.27
CBF in the semioval center	20.3 [16.8; 22.3]	16.3 [14.3; 19.9]	0.07
nTBF	3.1 [1.43; 4.4]	4.4 [3.0; 7.0]	0.13

***Note.** TBF – tumor blood flow; CBF – cerebral blood flow; nTBF – normalized tumor blood flow.*

Table 6. *Baseline characteristics of patients selected using propensity score matching (PSM): subgroup I (transcallosal approach) and II (transcortical approach)*

Characteristic	Subgroup		P-value
	I (*n* = 13)	II (*n* = 13)	
Mean age ± standard deviation, years	44 ± 15	44 ± 14	0.9
Sex, *n* (%): male female	4 (31) 9 (69)	5 (38) 8 (62)	1
Tumor size, *n* (%): large medium small	3 (23) 1 (8) 9 (69)	5 (38.5) 3 (38.5) 5 (23.0)	0.36
Tumor volume per T2-weighted MRI, cm^3 (median [quantiles])	3.8 [2.6; 18.4]	23.6 [8.1; 54.7]	0.08
Tumor location side, *n* (%): left right bilateral	6 (46) 4 (31) 3 (23)	4 (31) 8 (61) 1 (8)	0.37
Presence of hydrocephalus, *n* (%)	5 (38)	6 (46)	1
Evans index prior to surgery, median [quantiles]	0.28 [0.27; 0.34]	0.27 [0.26; 0.36]	0.7

Note. *See Note for Table 4.*

Table 7. *Preoperative ASL perfusion data of patients selected using propensity score matching (PSM): subgroup I (transcallosal approach) and II (transcortical approach)*

Blood flow characteristic, ml/100 g/min (median [quantiles])	Subgroup		P-value
	I (*n* = 13)	II (*n* = 13)	
TBF	39.7 [31.0; 97.0]	65.3 [47.0; 116.0]	0.29
CBF in the semioval center	20.1 [16.3; 21.8]	17.3 [14.2; 20.2]	0.26
nTBF	3.6 [1.3; 4.6]	4.4 [2.7; 7.0]	0.19

Note. *See Note for Table 5.*

Table 8. *Distribution per histological diagnosis in the total cohort of patients with space-occupying lateral ventricles lesions*

Histological diagnosis	Number of patients, *n* (%)
Giant cell astrocytoma	2 (4.2)
Subependymoma	10 (20.8)
Choroid plexus papilloma	1 (2.1)
Ependymoma	4 (8.3)
Epidermoid cyst	1 (2.1)
Benign glioma	5 (10.4)
Malignant glioma	5 (10.4)
Cavernoma	2 (4.2)
Colloid cyst	1 (2.1)
Meningioma	4 (8.3)
Metastasis	2 (4.2)
Neurocytoma	11 (22.9)
Total	*48 (100.0)*

RESULTS

Evaluation of radicality of tumor removal depending on surgical approach

In our cohort, most of the tumors were benign slowly growing neoplasms. Distribution of patients with LV tumors per histological diagnosis is presented in Table 8.

After surgery the following events were observed: escalation of pyramidal tract signs – 2, speech disorders – 2, escalation of amnestic disorders – 7, reduction of visual fields – 2, oculomotor disorders – 1. Among 4 patients with hemiparesis the following events were observed: escalation of pyramidal tract signs prior to surgery – 2, development of hemiparesis after surgery – 2. Dynamics of neurological and ophthalmological symptoms before and after surgery are presented in Tables 9 and 10.

Among 44 patients who underwent surgery through transcallosal and transcortical approaches, radical removal (residual volume per T2-weighted MRI, median – 0) was achieved in 30 (68 %) patients.

Outcomes of surgical treatment of LV tumors in groups I and II are presented in Table 11.

Table 9. *Neurological symptoms in patients with space-occupying lateral ventricles lesions (n = 48) before and after surgical treatment*

Neurological symptoms	Number of patients, *n* (%)	
	before surgery	after surgery
Paresis	4 (8)	6 (13)
Epileptic seizures	2 (4)	2 (4)
Speech disorders	0 (0)	2 (4)
Memory loss	22 (46)	27 (56)

Table 10. *Ophthalmological symptoms in patients with space-occupying lateral ventricles lesions (n = 48) before and after surgical treatment*

Ophthalmological symptoms	Number of patients, *n* (%)	
	before surgery	after surgery
Oculomotor disorders	0 (0)	1 (2)
Visual field loss	1 (2)	3 (6)
Condition of the ocular fundus:		
venous stasis	20 (42)	2 (4)
venous stasis with hemorrhage	6 (13)	0 (0)
normal	16 (33)	35 (73)
venous hyperemia	6 (13)	11 (23)

In the compared groups (I – transcallosal, II – transcortical approach), similar frequencies of radical tumor removal were observed (71 and 63 %, respectively). At the same time, hematomas in the tumor bed were more frequent in the transcortical patient group (64 vs. 31 % in transcallosal) but the differences are not statistically significant. In general, there were no statistically significant differences in the treatment results between groups I and II (p >0.05). This conclusion was confirmed for patient subgroups pseudo-randomized through PSM.

In the selected subgroups, total removal of tumors was more frequent through transcortical approach (70 %) compared to transcallosal approach (54 %) despite the fact that transcortical approach was used for large tumors (mean volume 23.6 and 3.8 cm^3, respectively). However, these differences did not reach statistical significance (Table 12).

Analysis of risk factors of hemorrhagic complications development in the early postoperative period

Data on the presence or absence of postoperative intracranial hemorrhage were available for 44 of 48 patients of the initially observed cohort. Hematoma in the tumor bed was observed in 23 (52 %) cases. Characteristics of these patients (with LVH) and patients who did not have hemorrhagic complications in the early postoperative period (21 (48 %) patients) are presented in Table 13.

Results of univariate analysis presented in Table 13 show that sex, tumor volume, presence of hydrocephalus prior to surgery and Evans index prior to surgery are statistically correlated with hematoma development in the tumor bed.

Analysis of the association between hematoma development in the postoperative period and initial blood flow in the regions of interest showed that in the group with postoperative hematomas TBF values prior to surgery were almost 2-fold higher than in the group without hemorrhagic postoperative complications (80.6 vs. 49.4 ml/100 g/min) (Table 14).

For hematoma development in the tumor bed the following postoperative parameters were statistically significant: presence of hydrocephalus and Evans index in the early postoperative period (Table 15).

Multivariate analysis using logistic regression model showed that hematoma development in the early postoperative period is significantly correlated with the following parameters:
- preoperative Evans index (in female patients increase of this parameter leads to higher risk of hematoma development than in male patients);
- sex – hematomas are more frequent in men;
- tumor blood flow – increase of this parameter increases the risk of intraventricular hemorrhage (IVH);
- tumor location – hematomas are less frequent for tumors in the projection of the anterior horn of the right LV.

This analysis was performed for 40 patients (22 – with the complication, 18 – without them). Results of model development (predictor coefficients) are presented in Table 16.

Table 11. *Results of surgical treatment of lateral ventricular tumors through transcallosal (group I) and transcortical (group II) approaches in the total cohort*

Characteristic	Group		P-value
	I (n = 16)	II (n = 28)	
Radical removal, *n* (%)	10 (63)	20 (71)	0.74
Residual tumor volume per T2-weighted MRI, cm^3 (median [quantiles])	0.0 [0.0; 0.35]	0.0 [0.0; 0.41]	0.89
Presence of hydrocephalus, *n* (%)	6 (36)	17 (61)	0.06
Evans index, median [quantiles]	0.29 [0.27; 0.31]	0.33 [0.27; 0.37]	0.12
IVH, *n* (%)	5 (31)	18 (64)	0.06

***Note.** IVH – intraventricular hemorrhage, MRI – magnetic resonance imaging.*

Table 12. *Results of surgical treatment of lateral ventricular tumors in patients selected using propensity score matching PSM with transcallosal approach (subgroup I) and transcortical approach (subgroup II)*

Характеристика Characteristic	Subgroup		P-value
	I (*n* = 13)	II (*n* = 13)	
Radical removal, *n* (%)	7 (54)	9 (70)	0.69
Residual tumor volume per T2-weighted MRI, cm^3 (median [quantiles])	0.0 [0.0; 0.35]	0.0 [0.0; 0.41]	0.98
Presence of hydrocephalus, *n* (%)	5 (38.5)	4 (31)	1.00
Evans index, median [quantiles]	0.29 [0.27; 0.31]	0.28 [0.26; 0.32]	0.66
IVH, *n* (%)	4 (31)	5 (38.5)	1.00

Note. *See Note for Table 11.*

Table 13. *Preoperative characteristics of patients with early postoperative hemorrhagic complications and without them*

Characteristics	Group		P-value
	with IVH (*n* = 23)	without IVH (*n* = 21)	
Sex, *n* (%): m f	 15 (65) 8 (35)	 5 (24) 16 (76)	0.008
Mean age. years ± standard deviation	40 ± 15	46 ± 14	0.2
Tumor size, *n* (%): large medium small	 9 (39.3) 10 (39.3) 4 (21.4)	 5 (19) 3 (12) 13 (69)	0.009
Tumor volume (T2-weighted MRI), cm^3 (median [quantiles])	31.2 [16.0; 57.2]	6.2 [3.1; 38.2]	0.009
Tumor location, *n* (%): on the left on the right bilateral	 10 (43.5) 10 (43.5) 3 (13)	 7 (33) 12 (57) 2 (10)	0.7
Hydrocephalus, *n* (%)	18 (88)	6 (29)	<0.001
Evans index before surgery, median [quantiles]	0.38 [0.32; 0.41]	0.27 [0.26; 0.30]	<0.001

Note. *See Notes to Table 11.*

Table 14. *ASL perfusion data prior to surgery depending on the presence of hematoma*

Blood flow characteristic, ml/100 g/min (median [quantiles])	Group		P-value
	with IVH (*n* = 23)	without IVH (*n* = 21)	
TBF	80.6 [50.3; 169.1]	49.4 [32.5; 83.7]	0.04
CBF in the semioval center	16.7 [14.7; 20.8]	18.1 [14.3; 21.2]	0.76
nTBF	5.04 [2.98; 9.83]	3.45 [1.8; 4.5]	0.04

Note. *See Notes to Tables 5 and 11.*

Testing of the model using data with which it was developed showed good quality of modeling: area under ROC curve – 0.952; accuracy – 0.95; sensitivity – 1; specificity – 0.889.

DISCUSSION

Space-occupying LV lesions are a relatively heterogenous group of tumors united by common location in the LV projection. Radicality of removal of these tumors is relatively high: per various sources it reaches about 80–90 % depending on tumor location, size, and histology [7–9]. Surgical approaches to LV neoplasms are quite exhaustively described in literature, indications and possibilities/limitations of tumor removal using different approaches considering location, hydrocephalus and advancement in the ventricular system are well known, and radicality of LV tumors removal is well described [1, 2, 5, 10].

The first aim of our study is selection of approach. It was based on well-known indications and contraindications taking into account location, presence of hydrocephalus,

Table 15. *Results of surgical treatment of patients with and without intracranial hemorrhagic complications*

Characteristic	Group		P-value
	with IVH ($n = 23$)	without IVH ($n = 21$)	
Radical removal, *n* (%)	16 (70)	14 (67)	1
Residual tumor volume per T2-weighted MRI, cm^3 (median [quantiles])	0.0 [0.0; 0.64]	0.0 [0.0; 0.35]	0.9
Presence of hydrocephalus, *n* (%)	18 (78)	5 (24)	0.001
Evans index, median [quantiles]	0.33 [0.31; 0.38]	0.28 [0.26; 0.29]	0.001

***Note.** See Notes to Table 11.*

Table 16. *Logistic regression model explaining interdependence between Evans index, tumor blood flow, tumor location and patient sex and probability of intraventricular hemorrhage*

Parameter	Coefficient	Standard error	Standard z-score	P-value
Constant	–30.562	11.624	–2.629	0.009
Evans index	68.362	25.941	2.635	0.008
Male sex	23.741	10.133	2.343	0.019
nTBF, ml/100 g/min	0.864	0.403	2.144	0.032
Tumor location in the projection of the anterior horn of the right lateral ventricle	–4.282	1.8760	–2.283	0.022
Evans index in males	–64.392	27.761	–2.320	0.02

***Note.** See Note for Table 5.*

tumor advancement. Transcortical approach offers wide view, which is important, especially in deep intraventricular tumor advancement. In case of severe hydrocephalus, transcortical approach allowed to remove tumors growing posteriorly into LV body and lateral parts. Using transcortical approach through the anterior horn, tumors of the anterior, middle and posterior locations at the side of approach could be removed, however there were limitations in removal of tumors in the opposite LV.

In our experience, transcallosal approach allowed to remove tumors of the anterior and middle location in both LVs but without lateral growth. Transcallosal approach has limitations in case of posterior tumor location. In cases of middle or unilateral medial tumor locations without lateral growth, transcallosal approach is preferred. This approach was used for tumors of small and medium size and when hydrocephalus was absent or mild. The advantage of transcallosal approach is possibility of accessing both LVs and absence of cortical incision [1, 2, 5, 10].

There are clinical situations when a tumor can be removed through both transcortical and transcallosal approaches. In this case selection of approach depends on the surgeon's preferences and experience.

Among 48 patients with space-occupying LV lesions operated on using different approaches, total removal was achieved in 67 % of cases. Typically, LV tumors are operated on through transcallosal or transcortical approach through the frontal lobe. Therefore, we have analyzed 2 groups of patients satisfying the inclusion criteria who underwent surgery using these approaches. Selection using PSM allowed to balance out baseline characteristics of the compared subgroups. The analysis showed that radicalities of LV neoplasm removal using the 2 main approaches are similar. Absence of statistically significant differences shows that in our series, selection of approach considering presence or absence of hydrocephalus was presumably adequate for the sizes, volumes, locations, advancement of the tumors in LV projection.

The performed statistical analysis shows that correct choice of approach taking into account tumor location, size and advancement does not allow to determine statistically significant factors that can affect radicality of LV tumor removal. As a rule, through transcortical approach large tumors can be removed which is a consequence of better visualization and wider attack angle compared to transcallosal approach [1, 5, 10].

Majority of researchers agree that one of the most dangerous complications in the postoperative period in LV neoplasm surgery is development of hemorrhagic complications, abnormal cerebrospinal fluid circulation (CSF) and escalation of neurological symptoms [1, 11].

According to data by M. Baroncini et al., frequency of postoperative intraparenchymal hemorrhages is 5.2 %, and IVH after LV tumor removal occurs in 6 % of cases [1]. IVH after removal of LV neoplasms are more common in cases of neurocytomas. According to A.N. Konovalov et al., hematoma in tumor bed is diagnosed in 20 % of cases, and it usually requires surgical revision and hematoma removal. In surgery of LV tumors, hemorrhagic complications are more common after removal of cerebral neurocytomas [10].

The second aim of the study is evaluation of factors affecting development of hemorrhagic complications in the early postoperative period. Knowledge of risk factors for these complications should improve their prevention during preparation for surgery. The performed analysis showed that after surgery in the early postoperative period hematoma in the tumor bed was observed in 23 cases. In 3 cases, hematoma led to occlusion of CSF with hydrocephalus and symptoms of hypertension. In these 3 observations, revision and hematoma removal were necessary. In the other 20 cases, lysis and resorption of hematomas occurred. Hematoma volume was not measured, only its presence or absence after tumor removal and analysis of factors affecting its development were considered.

Postoperative hematomas were more frequent (in 64 % of cases) after transcortical approach. For transcallosal approach, frequency of hematomas was 31 %.

Statistically significant predictors of hematoma development in tumor bed were Evans index, tumor location in the area of the right anterior horn (*for this location hematomas are rarer*), male sex and tumor blood flow level per ASL perfusion data. It can be suggested, that women with tumors in the right anterior horn are less likely to have postoperative hemorrhage compared to men. The risk increases with increasing Evans index and nTBF level. Presence of postoperative hematoma is correlated with Evans index because of the large size of tumors in cases of hydrocephalus. In the group with postoperative hematomas, hydrocephalus was observed in 78 % of cases. Additionally in our study, mean tumor size in the group of postoperative hematomas was 31.2 cm^3 compared to 6.2 cm^3 in the group without hematomas. For large advanced tumors, it is hard to control small residual tumor after removal. Visualization is complicated by collapse of the ventricular system at the end of surgery. Usually, residual tumor is the cause of hemorrhage in the postoperative period especially with high tumor blood flow.

For tumor location in the projection of the right anterior horn, hemorrhagic complications are less frequent because through transcortical and transcallosal approaches maximal visualization of the walls of the right LV is achieved. Other parts of the ventricular system remain less visible after LV tumor removal. Therefore, in the right anterior horn residual tumor can frequently be visualized and removed. Correlation between sex and hemorrhage is hard to explain. We did not find confirmation of this in the literature (PMC free article, PubMed, Google Scholar). Hemorrhages develop specifically from unremoved residual tumor. According to J.W. Kim et al., as well as L.F. Chen et al., postoperative hemorrhages develop due to the following factors: intense tumor blood flow, presence of many pathological vessels in the tumor, primarily arteries, without smooth-muscle elements and cavernous-like veins [11, 12].

Based on our study, significant factors allowing prediction of hemorrhagic complications in the postoperative period were determined: Evans index, tumor location in the area of the right anterior horn (*for this location hematomas are rarer*), male sex and tumor blood flow level per ASL perfusion data. Awareness of these factors affecting development of hemorrhagic complications allows surgeons to predict such pathologies and correctly prepare for surgical LV tumor removal.

CONCLUSION

Correct and adequate choice of surgical approach considering anatomical location and advancement of the tumor, presence of hydrocephalus and surgeon's preferences, ensures high radicality of removal. Absence of statistically significant differences for resection radicality through transcallosal and transcortical approaches shows correct choice of approach for high radicality of LV tumor removal. Factors affecting the risk of hemorrhagic complications in the early postoperative period should be taken into account: sex, presence of hydrocephalus, neoplasm location and blood flow level.

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Author's contribution

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G.V. Danilov: research design of the study, article writing and editing;
Yu.V. Strunina: data collection and analysis, scientific editing of the article;
A.V. Batalov: data collection and analysis;
Ya.O. Vologdina: data collection and analysis;
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