N.N. Burdenko Research Institute of Neurosurgery, Russian Academy of Sciences


Journal is indexed in RSCI (Russian Science Citation Index), PubMed/Medline, Index Medicus, Scopus/EMBASE, Ulrich’s Periodicals Directory, Google Scholar.

EDITORIAL BOARD

Editor-in-Chief A.N. Konovalov
Deputy Editor-in-Chief O.N. Dreval’
Executive Editor A.V. Kozlov
Science Editor B.A. Kadashev

Address of the editorial office:
4-ya Tverskaya-Yamskaya ul., 16, Moscow, 125047 Russia
N.N. Burdenko Research Institute of Neurosurgery
Tel. +7 (499) 972 8566
E-mail: vopr@nsi.ru
Managing Editor
V.K. Ivanikova

Art and Layout: MEDIA SPHERA Publishing Group

FUNDAMENTAL AND PRACTICAL JOURNAL

V.K. Ivannikova

The Editorial Board is not responsible for the content of advertising materials. Editorial opinion does not always coincide with the opinion of the authors. Only the articles prepared in compliance with Authors’ guidelines are accepted for publication. When submitting an article to the Editorial Board, the authors accept the terms and conditions of the public offer agreement. Authors’ guidelines and the public offer agreement can be found on website www.mediasphera.ru. Complete or partial reproduction is allowed by written permission of the Publisher (MEDIA SPHERA Publishing Group).

MEDIA SPHERA Publishing GROUP Moscow • MEDIA SPHERA Publishing GROUP Moscow
CONTENTS

ORIGINAL ARTICLES

Intraoperative Combined Spectroscopy (Optical Biopsy) of Cerebral Gliomas .......................................................... 3

Cherekaev V.A., Spirin D.S., Kadashcheva A.B., Kozlov A.V., Mikhailkova A.A., Mukhametzhanov D.Zh., Rotin D.L.,
Galkin M.V., Lasunin N.V., Grigorieva N.N.
Orbitosphenopetroclival Meningiomas: Clinical and Topographic Features and Results of Combined Treatment ........ 11

Shulyev Yu.A., Trashin A.V., Rychkov V.L.
Analysis of the Neurological Status and Functional Outcome after Facial Nerve Neuroplasty Using Accessory Nerve ....... 22

Sharma M.K., Chichanovskaya L.V., Shlemsky V.A.
A Comprehensive Study of Early Outcome (at the time of Discharge from the Hospital) after Lumbar Discectomy for Degenerative Spine Disease ................................................................. 28

PRACTICAL NOTES

Konovalov A.N., Pitskhelauri D.I., Shishkina L.V., Kopachev D.N., Sanikidze A.Z., Gavryushin A.V., Puchkov V.L.
Intraparenchymal Brainstem Schwannomas: Report of Three Cases and Literature Review ........................................ 32

Golbin D.A., Lasunin N.V.
The First Experience of Skull Base Defect Reconstruction Using Pedicled Buccal Fat Pad after Endoscopic Endonasal Resection of a Craniofacial Tumor ............................................................ 41

Glioneuronal Tumor with Neuropil-like Islands in a Neonate ...................................................................................... 46

DISCUSSIONS

Mlyavykh S.G., Sharamko T.G., Yulina D.P., Bokov A.E., Alevnik A.Ya., Shot A.V., Dzyubanova N.A., Zelenkov P.V.,
Working Results of the Electronic On-line Version of the Spine Registry for Degenerative Lumbar Spine Diseases and Study of Its Synchronization Capacity with the Electronic Case History ......................................................... 52

Microsurgical Selective Neurotomy in Treatment of the Focal Spastic Syndromes of Different Etiology ..................... 59

In accordance with the resolution of the Higher Attestation Commission of the Ministry of Education and Science of the Russian Federation, the N.N. Burdenko Journal of Neurosurgery was included in the List of Leading Peer-Reviewed Journals and Periodicals issued in the Russian Federation where the main results of Candidate and Doctor Theses are recommended to be published.
Intraoperative Combined Spectroscopy (Optical Biopsy) of Cerebral Gliomas

A.A. POTAPOV1, S.A. GORYAYNOV1, V.B. LOSCHENOVA2, T.A. SAVELEVA2, A.G. GAVRILOV1, V.A. OHLOPKOV1, V.Y. ZHUKOV1, P.V. ZELENKOV1, D.A. GOLBIN1, V.A. SHURAY1, L.V. SHISHKINA1, P.V. GRACHEV2, M.N. HOLODTSOVA2, S.G. KUZMIN1, G.N. VOROZHTSOV2, A.P. CHUMAKOVA3

1N.N. Burdenko Neurosurgical Institute, Russian Academy of Medical Sciences; 2Prokhorov Institute of General Physics; 3State Research Center “Research Institute of Organic Semiproducts and Dyes”; 4Faculty of Basic Medicine, Lomonosov Moscow State University, Moscow, Russia

Clinical studies have revealed high selectivity of 5-ALA-induced protoporphyrin IX accumulation in different brain tumors. Modern methods for evaluation of visible fluorescence of tissues are based on the qualitative analysis of the images. Up-to-date methods of combined spectral analysis allow one to fulfill the intraoperative quantitative evaluation of protoporphyrin IX content, as well as the scattering and absorption properties of a tissue. This paper presents a new method for simultaneous analysis of hemoglobin concentration in oxygenated and reduced forms, tumor marker (5-ALA-induced PP IX) concentration, and a new way to analyze the changes in the scattering properties of tissues. The method is implemented by splitting the visible spectrum into intervals where hemoglobin and protoporphyrin IX have the characteristic peaks of absorption and fluorescence. The present method shows the dependence between the fluorescence index and tumor grade. Combined spectroscopy (optical biopsy) can detect the differences between the subtypes of gliomas that are similar in the protoporphyrin IX fluorescence index. This method complements and enhances the diagnostic capabilities of spectroscopy, which is particularly important in non-fluorescent glioma surgery.

Keywords: glioma, 5-ALA, fluorescence-based diagnostics, combined spectroscopy.

Abbreviations:
5-ALA — 5-aminolevulinic acid
PP IX — protoporphyrin IX
DM — dura mater

The detection rates of central nervous system tumors have recently significantly increased [9]. The main challenge is to determine the boundaries of primary brain tumors due to the features of infiltrative growth of tumors along myelinated nerve fibers and vessels [10, 22], resulting in a high rate of postoperative relapses. Intraoperative imaging needs to be used to obtain reliable data regarding the volume of a resected tumor. This problem is typically solved using intraoperative computed tomography, magnetic resonance imaging, ultrasonography, and 3D frameless ultrasound-based neuronavigation, neuronavigation systems, and various combinations of these methods [8, 18, 21].

Taking into account the fact that MRI cannot always be used in an operating room, while intraoperative ultrasonography provides no data on metabolic parameters of the tumor, it seems rather topical to elaborate and improve intraoperative optical imaging and laser spectroscopy [16, 19, 24, 25]. The use of modern microscopes and endoscopes equipped with fluorescent filters enables only qualitative assessment of visible fluorescence, while the optical spectroscopy methods allow one to quantitatively assess intra-tissue accumulation of PP IX [14].

Clinical studies have shown a significant correlation between the PP IX accumulation level and cell division rate [12], enabling one to use this substance as a marker of tumor malignancy [26]. However, the substance is accumulated in tumor cells only in 30% of cases [1, 2, 15], thus making it necessary to use additional criteria for intraoperative diagnosis of tissues. These criteria include light scattering, blood filling, and oxygenation indices [20]. The changes in the scattering properties of tissues are caused by degradation of the structure of myelin sheath of the nerve pathway in white matter during tumor growth at the tissue level) and by the changes in the surface and structure of cell membranes at the cellular level. Furthermore, the light scattering is affected by the growth of the number and size of cell nuclei in case of a simultaneous decrease in the number of mitochondria caused by the transfer of tumor cells to glycolysis. Blood filling correlates with microvessel density, degree of hypoxia, and glioma malignancy [6, 7, 13].

Thus, simultaneous determination of these parameters enables one to enhance sensitivity of the method based on detection of concentration of the tumor marker (5-ALA-induced PP IX). Diffused reflectance spectroscopy is based on the analysis of the reflectance spectrum...
that underwent absorption scattering in the tissue, enabling one to determine concentration of the major absorbers and scattering elements at the micro-level [5]. Fluorescence spectroscopy and diffused reflectance spectroscopy are rapid and non-invasive methods for studying the metabolic and structural changes in tissues. Furthermore, concentration of the PP IX tumor marker in a biological environment can be determined during a surgery by measuring fluorescence intensity [4].

A similar approach to spectroscopic analysis has been reported in [24]. However, this approach assumes that the background radiation spectrum, two diffused reflectance spectra, and the fluorescence spectrum are recorded sequentially. The total time required to record these spectral dependences at each point is ~ 3 s. Unfortunately, the simultaneous measurements do not allow one to reliably state that they were recorded for the same point under equal conditions. Another drawback of this method is that shortwave radiation with 405 nm wavelength (violet light) is used to excite fluorescence. For this light, the biological tissue is a low-transparency medium, which results in penetration of radiation at depth less than several microns. In this connection, blood needs to be completely removed from the tissues before an optical measurement. These drawbacks make tissue analysis by means of optical biopsy more difficult. Furthermore, P. Valdes [25] has used combined spectroscopy for a small sample of patients (n=23) with WHO Grade I–IV gliomas, employing the simultaneous morphological analysis of 133 biopsy material samples [25].

This work was aimed at studying the potential of optical biopsy via combined spectral analysis in surgery of brain tumors using an original spectrum analyzer manufactured in Russia with fluorescence excitation wavelength of 632.8 nm, which allows one to simultaneously record the quantitative accumulation of PP IX, light scattering from tissues, oxygenation, and blood filling.

**Material and Methods**

The study comprised 90 patients (49 males and 41 females) aged 35–61 (average 51 years) with Grade II–IV tumors. The distribution of patients over histological variants of tumors is shown in **Table 1**. The number of patients with Grade II, Grade III, and Grade IV tumors was 14, 13, and 63, respectively.

<table>
<thead>
<tr>
<th>Tumor type</th>
<th>Grade</th>
<th>Number of patients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>abs.</td>
</tr>
<tr>
<td>Astrocytomas</td>
<td>II</td>
<td>5</td>
</tr>
<tr>
<td>Oligoastrocytomas</td>
<td>II</td>
<td>9</td>
</tr>
<tr>
<td>Astrocytomas</td>
<td>III</td>
<td>4</td>
</tr>
<tr>
<td>Oligoastrocytomas</td>
<td>III</td>
<td>9</td>
</tr>
<tr>
<td>Glioblastomas</td>
<td>IV</td>
<td>63</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>90</td>
</tr>
</tbody>
</table>

After the informed consent had been obtained, the patients administered 5-ALA hydrochloride solution (ALAsense agent manufactured by State Research Center “Research Institute of Organic Semiproducts and Dyes”, registration number LP-001848 dated September 21, 2012) at a dose of 25 mg/kg body weight 2–4 h before the surgery for tumor resection was started. The patients were operated on over the period between June 2010 and August 2012 at the N.N. Burdenko Neurosurgical Institute, Russian Academy of Medical Sciences, using visible fluorescence analysis and combined spectroscopy. A Carl Zeiss Pentero operating microscope (73 observations) and a Karl Storz endoscope with filters for fluorescent diagnostics (17), which enabled one to perform a qualitative assessment of tissue distribution of 5-ALA-induced PP IX, were used to assess visible fluorescence. The parameters described below for the intact cerebral cortex were measured prior to the main stage of the surgery after opening the DM.

The fluorescence index was calculated as the ratio between fluorescence intensity index of PP IX at 690–730 nm and the intensity of backscattered laser radiation. The fluorescent contrast was determined as the ratio between the fluorescence index of the tissue under study to that of the normal cerebral cortex.

Blood filling and oxygenation were calculated by analyzing the diffused reflectance spectra at 500–600 nm via deconvolution of the spectral dependence of the diffusely reflected radiation into components corresponding to the absorption spectra of reduced and oxygenated hemoglobin.

The scattering properties of tissues were assessed as the ratio between laser radiation backscattered by the tissue under study and the intensity of laser radiation backscattered by the intact brain. The intensity of laser radiation scattered by the intact white matter was assumed to be 1, while the intensity of radiation scattered by the cortex was assumed to be 0.5 according to the data regarding the ratio of their scattering properties [11].

Spectroscopic measurements were occasionally performed during the surgery for tumor resection (as well as before the stage of tumor bed hemostasis) in order to control the radicality degree of surgical intervention. Neurophysiological monitoring was used if the process localized near the functionally important zones.
A total of 1–21 tissue samples were collected from each patient to perform subsequent histological analysis and compare its results with the spectroscopy data. Thus, 268 tissue samples were analyzed: 216 samples collected from patients with glioblastomas; 21 samples from patients with Grade III tumors; and 31 samples from patients with Grade II tumors (Table 2).

A setup consisting of a LESA-01-BIOSPEC spectrum analyzer, two radiation sources (a He–Ne laser operating at 632.8 nm and a halogen lamp), optic fiber delivery means to deliver radiation to the tissue and back, as well as a PC with specialized software for interactive recording and analyzing spectra, was designed to simultaneously record the diffused reflectance spectra and laser-induced fluorescence spectra. The device used a cross-flow filtration system, which made it possible to separate the visible range of the spectrum into two subranges corresponding to registration of the diffused reflectance spectrum and fluorescence spectrum of PP IX. When performing the measurements, the distal end of the fiber optic probe was brought closer to the tissue until the contact was attained without exerting any pressure. As a result of the measurement, fluorescent, broadband and laser radiation diffusely reflected by the tissue enter the spectrometer inlet. The recorded spectral dependences are subjected to interactive mathematical processing in accordance with the algorithms described in [4, 5].

### Results and Discussion

**Differentiation of various types of cerebral gliomas via spectral analysis according to the fluorescence index of 5-ALA-induced PP IX**

The primary spectroscopic analysis of gliomas was conducted using the fluorescence indices. Parametric methods were employed to perform a statistical analysis of the differences between the groups of tumors of different grades. Figure 1 shows a clinical example of using the fluorescent diagnostics and combined laser spectroscopy in a 70-year-old female patient with Grade III glioma in the right-hand parietal-frontal-temporal area. A bright visible fluorescence of the tumor spreading to the cerebral cortex was observed during the surgery.

### Table 2. Number of biopsy samples of Grade II, III, and IV glial and mixed tumors

<table>
<thead>
<tr>
<th>Malignancy degree</th>
<th>Number of biopsy samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>II</td>
<td>31</td>
</tr>
<tr>
<td>III</td>
<td>21</td>
</tr>
<tr>
<td>IV</td>
<td>216</td>
</tr>
<tr>
<td>Including:</td>
<td></td>
</tr>
<tr>
<td>brain</td>
<td>14</td>
</tr>
<tr>
<td>infiltrative area</td>
<td>46</td>
</tr>
<tr>
<td>active area</td>
<td>129</td>
</tr>
<tr>
<td>necrotic area</td>
<td>27</td>
</tr>
<tr>
<td>Total</td>
<td>268</td>
</tr>
</tbody>
</table>

**Fig. 1. Clinical example. Intraoperative fluorescent diagnosis and laser spectroscopy in a 70-year-old female patient.**

a – with WHO Grade III glioma; preoperative MRI; b – intraoperative white-light image; c – intraoperative image in BL 400 mode; d – postoperative MRI; e – spectral dependences of diffusely reflected and fluorescent radiation for the normal and tumor tissue; f – diagram showing the ratio between the scattering properties and fluorescence intensity for the normal and tumor tissue (all parameters are standardized to the maximum value. This allows one to conclude that the scattering properties of a tumor are 6 times weaker as compared by the normal tissue; however, the tumor is characterized by fluorescence signal that is stronger over 20-fold).
Figure 2 shows the distribution of frequency of the experimental data on fluorescence indices for various tumor groups.

Pairwise comparison of WHO Grade II–IV gliomas in terms of the fluorescence index using dispersion analysis and Student’s t-test revealed statistically significant differences between WHO Grade II and III gliomas, as well as between WHO Grade II and IV gliomas (the confidence level less than 1%; $p<0.01$). However, no statistically significant differences between Grade III and IV tumors were detected, which attests to the necessity of analyzing an additional parameter when performing intraoperative spectroscopy in order to differentiate these tumors. The groups of oligoastrocytomas and astrocytomas of identical malignancy degree were combined into a single group, since the fluorescent index proved to be independent of the presence of an oligocomponent in the tumor (Table 3).

Since the distribution of data over fluorescence index is asymmetric, the following criteria were used to describe it: the median (value of an indicator separating the variation series of the sample into two equal parts: 50% of the “lower” units of the series are not greater than the median, while the “upper” 50% are not smaller than the median), the first and third quartiles.

**Differentiation of different types of cerebral gliomas using spectral analysis according to scattering**

The comparison of gliomas of different histological structure in terms of scattering level was conducted according to the same algorithm. The distribution of data (Fig. 3) for Grade II tumors with respect to the light scattering level was characterized by two maxima: one maximum corresponded to the level of ~0.6 (with respect to the intact brain), while the other one corresponded to 0.9, approaching the normal value. This fact made it necessary to separate the combined group of Grade II gliomas into two groups according to the light scattering level in order to conduct further analysis. No statistically significant effects on the light scattering level due to the presence of an oligocomponent in the glioma structure ($p<0.05$) have been detected.

When comparing Grade II–IV gliomas in terms of their scattering properties, statistically significant differences ($p<0.05$) in light scattering indicators were detected between these groups (Table 4).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Grade II</th>
<th>Grade III</th>
<th>Grade IV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>oligoastrocytomas</td>
<td>astrocytomas</td>
<td>oligoastrocytomas</td>
</tr>
<tr>
<td>Median</td>
<td>1.5</td>
<td>1.5</td>
<td>11.8*</td>
</tr>
<tr>
<td>First quartile (25%)</td>
<td>1.0</td>
<td>1.0</td>
<td>8.2</td>
</tr>
<tr>
<td>Third quartile (75%)</td>
<td>2.5</td>
<td>22.7</td>
<td>20.9</td>
</tr>
<tr>
<td>Number of samples (harvested from the tumor center)</td>
<td>19</td>
<td>12</td>
<td>16</td>
</tr>
<tr>
<td>Number of patients</td>
<td>12</td>
<td>14</td>
<td>14</td>
</tr>
</tbody>
</table>

*Note.* * – significant difference ($p<0.05$) from Grade II values (oligoastrocytomas and astrocytomas) only.
However, further analysis has revealed that the level of light scattering in 6 samples of Grade II tumor tissues (among 23 samples) with low light scattering did not differ from that in the group of Grade III gliomas. This fact gives grounds for concluding that benign gliomas have a heterogeneous structure; i.e., the light scattering indicators in this group of tumors are similar to those of Grade III gliomas.

**Differentiation of different types of cerebral gliomas using spectral analysis according to the blood filling and oxygenation levels**

A group of parameters (tissue hemoglobin index, which is further referred to as blood filling, and degree of hemoglobin oxygen saturation) was used to increase the accuracy of tissue differentiation in addition to the indicators described above. The distribution of oxygenation and blood filling values in patients with Grade II–IV gliomas is listed in Table 5. The small size of Grade II–III glioma sample and the use of intraoperative determination of the oxygenation and blood filling parameters do not allow one to draw any statistically significant conclusions about the differences between these groups. Further research is required.

The statistically significant differences between the groups of data related to the necrotic and active areas of the tumor (5% confidence level; $p<0.05$) were detected when analyzing the oxygenation degree and blood filling of tissues in different tumor areas in patients with glioblastomas using the Mann-Whitney U-test (Table 6).

Different intraoperative neuroimaging techniques are being widely used in modern clinical practice; fluorescent metabolic navigation using 5-ALA-induced PP IX as a tumor marker is one of these procedures. However, in some patients with cerebral gliomas PP IX is accumulated at a negligible concentration that is insufficiently high to induce visible fluorescence [1, 2, 16]. The identification of anaplastic areas of gliomas is also

---

**Table 4. Parameters of distribution of the analyzed tissue samples over scattering level for WHO Grade II–IV gliomas**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Grade II</th>
<th>Grade III</th>
<th>Grade IV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>oligoastrocytomas</td>
<td>astrocytomas</td>
<td>oligoastrocytomas</td>
</tr>
<tr>
<td>scattering &lt; 0.6</td>
<td>0.28</td>
<td>0.32</td>
<td>0.2*</td>
</tr>
<tr>
<td>scattering ≥ 0.6</td>
<td>0.93*</td>
<td>0.19*</td>
<td>0.2*</td>
</tr>
<tr>
<td>First quartile (25%)</td>
<td>0.19</td>
<td>0.22</td>
<td>0.13</td>
</tr>
<tr>
<td>Third quartile (75%)</td>
<td>0.36</td>
<td>0.46</td>
<td>0.43</td>
</tr>
<tr>
<td>Number of samples (harvested from the tumor center)</td>
<td>6</td>
<td>12</td>
<td>4</td>
</tr>
<tr>
<td>Number of patients</td>
<td>9</td>
<td>10</td>
<td>46</td>
</tr>
</tbody>
</table>

*Note.* *–* *p*<0.05.
rather significant [1, 2, 17]. In this connection, laser spectroscopy is used to quantitatively assess the accumulation of PP IX [1–3, 15, 17, 23–25]. The spectral analysis has shown an increase in fluorescence of 5-ALA-induced PP IX depending on tumor grade for all types of astrocytic tumors. However, the fluorescence indices of Grade III and IV gliomas showed no statistical difference. Thus, it seems reasonable to use additional options of combined spectroscopy, including the analysis of scattering in tissues, oxygenation, and blood filling, as well as simultaneous quantitative assessment of accumulation of PP IX.

As opposed to the data obtained by P. Valdes [24, 25], who has carried out combined spectroscopic examination of patients with cerebral gliomas for a small sample (23 patients), we used this method in 90 patients. Furthermore, the use of the original LESA-01-BIOSPEC spectrum analyzer manufactured in Russia allowed us to perform simultaneous measurements of the fluorescence, light scattering, oxygenation, and blood filling indices (as opposed to the values measured by P. Valdes). P. Valdes performed the measurements in a sequential manner. This does not give grounds for reliably claiming that the spectra were obtained for the same point under identical conditions. As opposed to P. Valdes who employed a violet laser operating at 405 nm to excite fluorescence, we used a red laser operating at 632.8 nm. The light of the red laser significantly better penetrates into the tissue with blood present on it.

When analyzing the light scattering indicators, statistically significant differences were revealed between WHO Grade III and IV gliomas. The data regarding the difference in light scattering indicators between the subgroups of Grade II gliomas also seem to be rather interesting. Close scattering levels were detected in patients with Grade III gliomas, attesting to the heterogeneity of benign gliomas in terms of cellular and tissue structure. The differences in light scattering between the intact and pathological tissues are associated with heterogeneity of membrane structures, the changes in the number of mitochondria and size of nuclei in tumor cells.

Assessment of oxygenation and blood filling levels in patients with glioblastomas revealed a difference between the necrotic area and the area of active tumor growth. Thus, a preliminary analysis of data has demonstrated that the use of combined spectroscopy allows one to enhance the diagnostic value of laser spectroscopy and considerably broaden its potential by performing intraoperative morphological assessment of the tissue structure. This fact gives grounds for using the term “optical biopsy” when performing a study.

The aforementioned data allow one to obtain a general pattern of spectroscopic parameters and corresponding physiological changes for different types of glial tumors. However, intraoperative demarcation of the glioma boundaries is the most interesting application of this method in neurosurgery. In order to assess the effect of combined spectroscopy on the degree of

| Table 5. Parameters of distribution of the analyzed tissue samples over oxygenation and blood filling levels for Grade II–IV gliomas |
|--------------------------|----------------|----------------|
|                         | Grade II | Grade III | Grade IV |
| Hemoglobin oxygen saturation (relative to the intact cortex) |       |       |       |
| Median                   | 0.54    | 0.3    | 0.81    |
| First quartile (25%)     | 0.45    | 0.17   | 0.72    |
| Third quartile (75%)     | 0.63    | 0.43   | 1.0     |
| Blood filling level (relative to the intact cortex)     |       |       |       |
| Median                   | 1.33    | 0.73   | 1.91    |
| First quartile (25%)     | 1.15    | 0.72   | 1.13    |
| Third quartile (75%)     | 1.54    | 0.73   | 3.50    |
| Number of samples (harvested from the tumor center)     |       |       |       |
| Number of patients       | 1       | 1      |         |

| Table 6. Parameters of distribution of the analyzed tissue samples over hemoglobin oxygen saturation and blood filling for WHO Grade IV tumors |
|--------------------------|----------------|----------------|----------------|
|                         | Active area of the tumor | Infiltrative area | Necrotic area |
| Oxygenation level (relative to the intact cortex) |       |       |       |
| Median                   | 0.81*   | 0.65   | 0.39*   |
| First quartile (25%)     | 0.72    | 0.57   | 0.29    |
| Third quartile (75%)     | 1.00    | 0.81   | 0.55    |
| Blood filling level (relative to the intact cortex)     |       |       |       |
| Median                   | 1.91*   | 1.90   | 7.29*   |
| First quartile (25%)     | 1.13    | 1.51   | 5.31    |
| Third quartile (75%)     | 3.50    | 3.68   | 8.71    |

Примечание. * — p<0.05.
radicality of tumor resection, further research needs to be conducted, including the assessment of the data by postoperative MRI.

Conclusions

The proposed method of optical biopsy, which consists in conducting a spectral analysis of hemoglobin concentration in oxygenated and reduced forms, tumor marker (5-ALA-induced PP IX) concentration, and the changes in scattering properties of the tissues under study, has demonstrated that different subtypes of glial tumors that are similar in terms of fluorescence of PP IX but differ in other parameters can be differentiated. The results of classification of the spectroscopy data as compared to the morphological analysis have demonstrated that different tumor zones in patients with glioblastomas can be identified intraoperatively. This makes it possible to perform an express optical intraoperative diagnosis and detection of glioma foci with high proliferative activity and to presumably estimate the radicality of tumor resection. The optical biopsy method with the combined biospectral analysis increases the reliability of measurements, the rate of data acquisition, the probing depth, and makes the in vivo recording of spectra easier.

REFERENCES

5. Stratonnikov A. The use of reverse diffuse reflectance spectroscopy to monitor tissue condition when performing photodynamic therapy. Quantum Electronics 2006; 36: 12: 1103—1110.

Commentary

The article by A.A. Potapov et al. “Intraoperative Combined Spectroscopy (Optical Biopsy) of Cerebral Gliomas” reports the data on using combined laser spectroscopy in surgery of cerebral gliomas. The clinical studies have demonstrated the high efficiency of using 5-aminolevulinic acid (5-ALA) for intraoperative fluorescent diagnosis of different types of cerebral tumors. However, some patients demonstrated no effect of visible fluorescence or had similar indicators of protoporphyrin IX accumulation in different glioma subgroups. This limitation of the method can be partially overcome by using photodynamic detection of quantitative laser spectroscopy with respect to protoporphyrin IX. In order to broaden...
the capacity of this method, a simultaneous analysis of additional parameters of spectral study (hemoglobin concentration in oxygenated and reduced forms; scattering properties of tissues) is employed. The authors have reported the features of the spectral parameters under study for different types of cerebral gliomas.

Generally speaking, the article by A.A. Potapov et al. is rather topical and on-demand for clinical use in neuro-oncology; it is aimed at solving the fundamental problems of intraoperative neuronavigation in surgery of this tumor group.

_O.N. Dreval' (Moscow)_
Meningiomas are the most common primary CNS tumors; the annual incidence rate is about 7 cases per 100,000 population [11]. Despite the advance in surgical techniques, the number of successful cases of radical (Simpson grade I [26]) resection of an intracranial meningioma is extremely small. The number of relapses in long-term follow-up period is as high as 91% [17], while the increased radicality by using extensive surgical approaches worsens patients’ quality of life [3, 15]. Addition of stereotactic radiotherapy and radiosurgery to the treatment protocol for patients with meningiomas may significantly improve the survival and morbidity rates [1, 2, 14].

Meningiomas can be either local (nodular) or infiltrative (spreading to the adjacent tissues and the brain) [10, 17]. Some cases where the nodular and infiltrative growth types are combined have been reported. In patients with multiple meningiomas, one tumor can be infiltrative, while another one can be nodular [2, 4, 12, 15].

The invasive growth often does not correlate with the histological characteristics of the tumor, and the microscopically benign meningiomas can affect bones, muscles, cartilage tissue, mucous membranes, nerves, and vessels in the same manner as cancer and sarcoma do [8, 15].

These tumors may spread to anatomical areas that are not typical of meningiomas (namely, paranasal sinuses, infratemporal fossa, parapharyngeal space) and affect the temporomandibular joint. Management of infiltrative sphenopetroclival meningiomas affecting the cavernous sinus, the medial parts of the sphenoid bone wings, diaphragm of sella turcica, and great vessels is one of the most challenging tasks. The common strategy nowadays includes the maximal possible resection of the tumor followed by radiation therapy [1, 2, 5, 8, 20, 24, 29].

Patients with infiltrative sphenopetroclival meningiomas spreading to the orbit and the infratemporal fossa are attributed to an individual group. Sporadic cases of this type of meningiomas have been reported [4, 6, 12, 15, 16, 19]. The clinical presentation differs from that for the classical sphenopetroclival meningiomas. For example, the oculomotor disorders can be indicative of lesions either in the posterior cranial fossa, or in the cavernous si-

The aim of the study was to access clinical and topographic features of orbitosphenopetroclival meningiomas and the results of surgical and combined treatment in patients with meningiomas of that location.

**Introduction.** Orbitosphenopetroclival meningiomas comprise a peculiar group of tumors and result from progression of infiltrative sphenopetroclival meningiomas, when the latter extend into the orbit and infratemporal fossa. The advance in neurosurgery and the application of modern approaches and adjuvant therapies (such as stereotactic radiosurgery and radiotherapy) over the past years have considerably improved treatment outcomes in these patients. However, difficulties associated with the choice of treatment strategy still remain. One attempting to excise a tumor radically encounters a risk of damaging the crucially important neurovascular structures. When a tumor is excised partially, the risk of complication dwindles; however, the relapse risk increases. Palliative surgery improves patients’ quality of life. Radiosurgery and irradiation of residual tumors allow one to establish control over tumor growth.

**Material and Methods.** Twenty three patients were studied; 20 of them received surgery, 9 patients were subjected to stereotactic irradiation, and 5 patients underwent the conventional irradiation. The follow-up period was 8–84 months (median 37 months).

**Results.** Manifestations of orbitosphenopetroclival meningiomas consist of signs and symptoms of cranio-orbital and petroclival meningiomas, and in many patients include signs of involvement of the external surface of skull base, marked cosmetic defects, and psychological distress. Orbitosphenopetroclival meningiomas originate from cavernous sinus and medial parts of sphenoid bone wings. During its progression a tumor extends onto the orbit and clivus, and then onto infratemporal and sphenopalatine fossae, nasopharynx and posterior cranial fossa.

**Conclusion.** If a residual tumor is present, patients with orbitosphenopetroclival meningiomas need to undergo adjuvant irradiation after the first surgery.

**Keywords:** meningioma, skull base, orbitosphenopetroclival meningiomas, craniofacial tumors, irradiation, radiosurgery.
nus, or the orbit. A different surgical strategy is used in this case, since an extended approach is needed to resect the tumor from the orbit (and frequently from the infratemporal fossa and the adjacent structures of the outer skull base as well). Hence, we suggest that these patients should be attributed to a special group, while the tumors spreading to the orbit, mesocranial fossa, and the petroclival joint should be referred to as orbitosphenopetrosclival meningiomas (OSPCM) with allowance for specific methods of diagnostics and treatment that need to be used. The characterization given below and analysis of our data justify isolation of this classification unit.

**Material and Methods**

The observation group included 23 patients (4 men and 19 women; 1:4.8 ratio) aged 29–66 years (median age of 50 years), who underwent treatment at the Burdenko Neurosurgical Institute for OSPCM during the period 2006–2012.

In addition to general clinical examination, all the patients underwent contrast-enhanced MRI and/or CT of the brain, as well as neurological, neuro-ophthalmological, and otoneruological examination. The functional status of the patients before and after surgery was assessed using the Karnofsky scale [13]. The control examination was performed in the early (up to 10 days) postoperative period, 6 and 12 months after surgery, and subsequently each year.

A total of 20 patients were operated on (including 7 surgery native patients and 13 patients who had previously undergone one or several resections of meningioma disseminated to a lesser extent). Two patients refused surgery. In one case, the surgery was postponed because of exacerbation of acute sinusitis.

All surgical interventions were performed under combined endotracheal anesthesia. Prior to making a skin incision, isovolemic hemodilution was performed and 800 ml of autoblood was collected (the blood was re-infused at the final stage of the surgery). The blood was collected from the wound into a Cell Saver bowl. Second-generation cephalosporin was used for perioperative antibiotic prophylaxis.

In most cases, tumors were resected though an orbitozygomatic approach. The pterional approach and the approach through the frontal sinus were used in one case each. Seven patients underwent cerebral angiography or MR angiography prior to surgery; preoperative embolization of the vessels that supply the tumor was performed in 2 patients. The completeness of tumor resection was determined based on the intraoperative assessment and contrast-enhanced MRI/CT on day 1–10 after surgery.

Nine patients subsequently underwent a course of fractionated stereotactic radiation therapy: 8 patients – on a Novalis linear electron accelerator (Varian Medical Systems, USA and Brain LAB, Feldkirchen, Germany) and 1 patient – on an Elekta Axesse linear electron ac-

**Results**

The median age of disease manifestation was 41.5±10.5 years. The median period between the onset of symptoms and diagnosis was 2 years (from 2 months to 10 years).

The clinical presentation in patients with this type of disseminated tumors was polymorphic. The symptoms included the lesion of the base of the anterior, middle, and posterior cranial fossae and orbit; focal and general cerebral symptoms, and marked cosmetic deficits. **Figure 1** shows the main clinical symptoms in patients with OSPCM; craniobasal disorders are characterized in **Fig. 2**.

All patients had an exophthalmus (1.5–20 mm; median size – 5 mm). Most patients had oculomotor disorders. Reduced visual acuity and chiasmatic syndrome were detected in a many individuals. Almost 50% patients had unilateral amaurosis. Another frequent symptom was trigeminal nerve dysfunction, which manifested itself as reduced sensation in the area of innervations of the first branch. Some patients had symptoms of both dysfunction and irritation of the branches of the trigeminal nerve and disorders of the masticatory muscles. If the tumor spread to the posterior cranial fossa, the characteristic presentation of dysfunction of the VII–X and XII cranial nerves and trunk–cerebellar symptoms developed sequentially. It should be mentioned that hearing loss in patients with OSPCM was more frequently associated with dissemination of the tumor to the infratemporal fossa (resulting in compression of the eustachian tube and development of conductive hearing loss) rather than being caused by VIII nerve dysfunction only. The involvement of the infratemporal fossa was also manifested as limited mouth opening.

Cosmetic deficits (such as exophthalmus, deformity of the temporozygomatic area, cicatrical changes and dysfunction of the frontal branches of the facial nerve after previous surgeries, trophic disorders, edema of the
facial soft tissues because of disruption of the venous drainage) were observed in all patients. Emotional and other types of psychological distress were also observed rather frequently and were caused both by the lesions of the mediobasal parts of the frontal and temporal lobes and by reactive symptoms in patients who had undergone

**Fig. 1.** Symptoms of orbitosphenopetroclival meningiomas.

**Fig. 2.** Craniobasal disorders in patients with OSPCM. II–XII – cranial nerves (dysfunction); V1–V3 – branches of the trigeminal nerve.
reoperations and had marked cosmetic deficits, vision and other neurological impairments that considerably worsen quality of life.

The mean Karnofsky score used to assess patients’ status prior to surgery (for surgery naïve patients) was 71.5 (ranged from 50 to 90). Among 20 patients who underwent surgical intervention, 13 were operated on for recurrent tumor 1 to 12 years (median value of 3 years) after the first surgery. In addition to disseminating to the orbit, middle cranial fossa, and petroclival joint area, the tumor spread to the chiasmal sellar region in 16 (69.6%) patients, to the infratemporal fossa in 14 (60.9%) patients, and to the pterygopalatine fossa in 7 (30.4%) patients. In 12 (52.2%) cases, meningioma spread to the paranasal sinuses (sphenoidal, ethmoid, and maxillary ones). In 7 (30.4%) cases, the tumor was confined to the anterior cranial fossa; in 6 (26.1%) and 5 (21.7%) cases, it spread to the nasopharynx and the temporomandibular joint, respectively; in 3 (13%) patients, it affected the eyeball. In 2 (8.7%) patients, the tentorium of cerebellum was also affected (Figs. 3, 4).

Invasion of meningioma to the adjacent cranial bone and development of ostotic changes was observed in all cases.

The neurovisual characteristics of the tumor were dynamically assessed in 8 patients. In all observations, the tumor originally occupied the area of the cavernous sinus; formed a node in the middle cranial fossa in 6 cases, or affected the ipsilateral orbit in 5 cases. As the tumor progressed, its dissemination to the infratemporal fossa (6 cases), pterygopalatine fossa (4 cases), paranasal sinuses (5 cases), and clivus (4 cases) was revealed. Figure 5 shows an example of natural progression of OS-PCM; Fig. 6 demonstrates the expansion of the tumor within the inner and outer tables of skull base.

The localization of the tumor remnants after subtotal resection was analyzed in 16 patients using the surgery protocols and postoperative CT/MRI scans of the brain. Tumor remnants localized in the middle cranial fossa and in the cavernous sinus in 9 (56.3%) and 8 (50%) cases, respectively. The tumor remnants were detected in the sphenoid sinus in 3 (18.8%) cases, and in 3 cases they were detected in the area of tentorium of cerebellum. It was impossible to perform complete resection of the tumor near the superior and/or inferior orbital fissure in 3 patients. The residual tumor also localized in the posterior cranial fossa in 2 (12.5%) patients; near the diaphragm of sella turcica in 2 (12.5%) patients; in the anterior cranial fossa in 2 patients; and in the orbit in 2 patients. The tumor remnants were detected in the infratemporal fossa, in the clival and suprasellar area in 1 (6.3%) patient.

Combined surgical interventions consisting of tumor resection and resection of the temporomandibular joint (1 patient), removal of the eyeball (2 patients), preliminary implantation of a skin expander followed by plastic reconstruction of the skin defect at the site of bone infiltration after it had been removed (1 patient) were performed in some cases.

![Fig. 3. Tumor localization on the outer and inner skull base.](image-url)
Fig. 4. Examples of MRI scans of patients with orbitosphenopetroclival meningiomas.

a – contrast-enhanced T1-weighted MRI: OSPCM spreading to the chiasmal sellar region and extracranially growing into the infratemporal and pterygopalatine fossae, nasal cavity, and temporomandibular joint (patient К.); b – contrast-enhanced T1-weighted MRI: tumor continued to grow into the chiasmal sellar region, posterior fossa, grew parapharyngeally into the pterygopalatine fossa, the sphenoid sinus, and the medial parts of the middle cranial fossa after reoperations (patient Ш.).
Fig. 5. Disease progression.
a – tumor localization when the disease was diagnosed primarily (cavernous sinus, area of the sphenoid wings and the tentorium of cerebellum (2001)); b – 4 years later (before surgery), tumor localized in the orbit, middle and posterior cranial fossae on the left side and in the cavernous sinus on the right side, as well as in the anterior cranial fossa and chiasmal sellar region (2005); c – angiography (2005).
The volume of intraoperative blood loss ranged from 250 to 3800 ml (median volume of 750 ml). Automatic blood reinfusion was performed in 5 (23.8%) patients; in the remaining cases, autoerythrocytes were not reinfused due to the small volume of blood loss. Six (28.6%) patients with giant OSPCM with abundant blood supply underwent plasmapheresis and procurement of frozen autoplasma prior to surgery. Nine (42.9%) patients required transfusion of blood components from donors: quarantined frozen plasma (7), erythrocyte mass (7), and tromboconcentrate (1).

Two patients had postoperative hemorrhagic complications: hemorrhage from wound edges – 1 (5%) patient and hematoma to residual tumor in the posterior cranial fossa area – 1 (5%) patient. Four (20%) patients had liquorhea in the postoperative period. Purulo-septic complications developed in 3 patients: osteomyelitis of bone flap in 1 (5%) patient; meningitis in 2 (10%) pa-
tients, and meningoencephalitis followed by sepsis, pneumonia and pyelonephritis in 1 patient. Two (10%) patients had transient sensory or sensorimotor aphasia. Psychological distress emerged or aggravated in 2 (10%) cases. Ischemic disease in the hemisphere ipsilateral to the tumor developed in two (10%) patients; either chronic or transient hemiparesis was observed.

Either complete (15 patients; 75%) or partial (exophthalmus > 2 mm; in 5 (25%) patients) repositioning of the eyeball was attained in all 20 patients immediately after the surgery. Enophthalmos subsequently developed in the long-term follow-up period in 4 (20%) patients. Two patients with amaurosis underwent extraction of the eyeball because of infiltration with tumor and the marked trophic changes in the eye bulb. The dynamics of visual and oculomotor functions are listed in Table.

Two patients died in the postoperative period. In one case, a female patient with original thrombocytopenia had a hematoma to tumor remnant in the posterior cranial fossa 2 weeks after surgery. The other female patient died 15 weeks after surgery from puruloseptic complications. Thus, the postoperative mortality rate was 10%.

Either complete or partial regression of symptoms was observed after surgery in all patients with retrobulbar pain, chemosis, and eyelid edema. The mean Karnofsky score for the status of patients operated on at discharge was 71.1 (ranging from 60 to 80). This indicator did not change significantly compared to the preoperative one (p=1.000000).

According to the histological assay, meningioma was typical (Grade I) in 17 (85%); atypical (Grade II) in 1 (5%); and anaplastic (Grade III) in 2 (10%) observations. In 3 patients who had refused surgery, the histological diagnosis was not verified. However, taking into account the clinical and neuro-visualization presentation (duration of disease ranging from 2 to 15 years) one can assume that the meningioma was typical. One anaplastic and one atypical meningioma developed from primarily typical tumors.

Radiotherapy was performed for 14 patients (in 4 patients, after one surgery and in 9 patients, after reoperations). In all four patients subjected to radiation therapy, no recurrence was observed after the first surgery during the follow-up period from 4 to 77 months (median time 28 months). Radiation therapy was performed after a surgery for tumor recurrence in 9 cases. In one patient, it was performed after tumor recurrence had been revealed without reoperation. The median follow-up period in this group was 33.3 months (ranging from 6 to 77 months). Recurrent meningioma was observed in 5 patients after completing radiotherapy within the period ranging from 6 to 60 months (median time 31.8 months). Meningioma was typical in 3 cases; atypical in 1 case; and anaplastic in 1 case. One of these patients (who had been operated on three times for infiltrating meningotelomatous meningioma) was subjected to two courses of radiation therapy (TBD of 59.6 and 55.8 Gy); no recurrence was observed within the follow-up period of 27 months. Tumor growth stabilized in 5 patients after the radiotherapy for meningioma recurrence. The follow-up period ranged from 8 to 39 months (median of 25.4 months).

**Discussion**

Women were predominant in the gender structure of patients with OSPCM, identically to that of patients with meningiomas of other localization [10]. The first OSPCM symptoms in the first half of observation period appeared before 40 years of age, while cranio-orbital and petroclival meningiomas are characterized by manifestation at the age of 40–50 years [18, 21, 23, 24]. Taking into account the fact that the period between meningioma emergence and manifestation of the first clinical signs is usually 20–30 years [27], it can be supposed that OSPCM in many cases emerge in childhood.

In our data, therapy was started more than 2 years after clinical manifestation of the disease in half of all cases. This could have also caused wide dissemination of tumor in patients with OSPCM and, in turn, had a negative effect on the volume of resected tissues.

Identically to the situation with cranio-orbital meningiomas, the key symptoms of the tumor process in patients with OSPCM included exophthalmus, reduced vision acuity, and oculomotor disorders [9, 12]. In addition, most patients (78.3%) also had trigeminal nerve dysfunction, which is typical of petroclival meningiomas [4, 5, 7]. Thus, the set of symptoms in patients with orbitophenopetral meningiomas, as it can be expected from their topographic localization, combines the clini-

---

**Table.** Dynamics of visual and oculomotor functions in operated patients

<table>
<thead>
<tr>
<th>Symptom at admission</th>
<th>Before surgery</th>
<th>Aggravation in the early postoperative period</th>
<th>Aggravation continued in the late postoperative period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ophthalmoplegia</td>
<td>7</td>
<td>No dynamics</td>
<td></td>
</tr>
<tr>
<td>No oculomotor disorders</td>
<td>2</td>
<td>1</td>
<td>0*</td>
</tr>
<tr>
<td>Oculomotor disorders</td>
<td>11</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Blindness</td>
<td>11</td>
<td>No dynamics</td>
<td></td>
</tr>
<tr>
<td>Normal vision</td>
<td>2</td>
<td>2</td>
<td>0*</td>
</tr>
<tr>
<td>Reduced vision acuity</td>
<td>7</td>
<td>5</td>
<td>4</td>
</tr>
</tbody>
</table>

*Note.* *One patient died 2 weeks after surgery.*
cal manifestations typical both of cranio-orbital and petroclival meningiomas. OSPCM are also characterized by symptoms of involvement of the outer skull base (in particular, the infratemporal and pterygopalatine fossae) and marked cosmetic defects. These defects, together with the strain imposed on the medial and basal portions of the frontal and temporal lobes cause considerable psychological and emotional distress and significantly reduce patients’ quality of life.

In all observations, at least a tumor portion localized in the area of the middle cranial fossa. An analysis of the dynamics of natural development of the tumor (which could be performed in 8 cases) revealed a primary lesion of the cavernous sinus and the adjacent structures of the base of the middle cranial fossa. This fact allows one to draw a conclusion that OSPCM is a chronically progressive or even a neglected variant of meningiomas of the middle cranial fossa with the origin near the medial parts of sphenoid bone wings. Similar results were obtained by H. Bloss et al. [7] as they studied the growth pattern of meningiomas of sphenoid bone wings. Thus, the tumor spread to the cavernous sinus in 34.1% of cases; to the area of the superior orbital fissure in 34.1% of cases; to the optic canal in 36.4% of cases; and to the periorbit in 25% of cases. All the tumors expansively grew into the adjacent tissues; simultaneous spreading of meningioma to multiple anatomical regions was observed. Furthermore, the localization of the soft-tissue tumor component in the cavernous sinus (which was observed in all observations within our series) and hyperostosis in the area of the superior orbital fissure and the orbit were the prognostic factors for recurrence (p=0.002).

Numerous studies [9, 22, 23, 25] devoted to surgical treatment of cranio-orbital and sphenopetroclival meningiomas report that total tumor resection near the cavernous sinus, the superior orbital fissure, inside the orbit, and near the cranial nerves and vessels in the medial part of sphenoid bone often cannot be performed. The tumor grew into the cavernous sinus in all observations within our series; tumor fragments remained in the superior or inferior orbital fissures and in the orbit in several cases after the surgery. We deemed it reasonable to stop tumor resection if it was found that it affects functionally important and vital structures as cranial nerves and main arteries. If structures could not be identified (in particular, in the cavernous sinus and the superior orbital fissure), a ~5 mm thick layer of tumor tissue in the projection of these structures was left unresected. Growth of OSPCM into the posterior cranial fossa, into the sella turcica region and extracranial growth into the infratemporal fossa and the sphenoid sinus also made it impossible to perform the total tumor resection.

The volume of intraoperative blood loss was significant as a result of large tumor size and the demand for resection of the hyperstastically changed cranial bones. Thus, some auxiliary procedures had to be used (such as preoperative embolization of the vessels supplying the tumor, automatic erythrocyte reinfusion, preoperative plasmapheresis to procure autoplasm, and transfusion of donor blood components in 60% of patients).

The frequency of hemorrhagic, purulo-septic, and ischemic complications, aphasia, and mental disorders was less than 15% and was comparable to the rate of complications after resection of cranio-orbital and sphenopetroclival meningiomas [20, 23, 28, 29]. Meanwhile, high rate (25%) of postoperative liquororrhea was observed in our series, which can be attributed to the extensive growth of the tumor to the skull base and the fact that the postoperative defect of large area spread to the paranasal sinuses (plastic closure of this defect is associated with some technical problems).

Either partial or complete regression of exophthalmus was attained after the surgery in all cases. Thus, tumor resection also ensured a cosmetic effect. Meanwhile, repositioning of the eyeball was incomplete in 25% of patients and an exophthalmus at least 2 mm in size remained. All these patients were operated on for recurrent OSPCM. We believe that incomplete exophthalmus regression in these cases was caused by chronic disruption of venous outflow from the orbit associated with the involvement of its apex and the superior and inferior orbital fissures into tumor growth, which resulted in development of fibrosis and rigidity of the orbital contents [20].

Vision acuity was improved in neither case after surgery. The reason behind this was probably the fact that the optic nerve was being compressed by the tumor for a long time and was partially atrophied. Although postoperative visual impairment has been reported in most studies focused on surgical treatment of cranio-orbital meningiomas only in 0–9% of cases [20, 23, 28, 29], vision acuity decreased in the postoperative period in most patients in our series who had it prior to surgery. Vision impairment was stable in half of these patients. The reason behind that may be either the infiltrative nature of meningioma growth and intraoperative injury of the optic nerve during its traction when resecting the tumor or disruption of blood supply of the optic nerve because of sharing blood supply with the tumor.

The functional status of patients according to the Karnofsky scale remained unchanged after surgery and was 71.1, which implies that a person remains capable of self-maintaining in daily life but cannot have an active labor and social activity. However, the young age of patients with OSPCM makes the problem of their social adaptation particularly topical.

At the time of writing, no signs of tumor recurrence have been detected in all 4 cases when radiotherapy was performed after the first surgery for resection of OSPCM. On the other hand, among 14 patients who had been operated on for continued tumor growth, the conventional radiotherapy was performed in 1 case only. Continued growth of OSPCM with spreading to the adjacent anatomical regions and progression of a neurological deficit was observed within the first 3 years after surgery.
in all 13 patients who had not timely received radiation therapy. A course of adjuvant radiation therapy could probably have allowed one to prevent tumor progression and avoid reoperation and the risks associated with it. The number of cases and follow-up period are insufficient to draw any final conclusions. The study needs to be continued; however, the trend is clear.

Conclusions

Orbitosphenopetrosclival meningiomas are characterized by long-lasting growth, resulting in extensive infiltrative extra- and intracranial dissemination, multiple neurological deficit, and marked ophthalmological symptoms. The set of symptoms of orbitosphenopetrosclival meningiomas combines clinical manifestations that are typical of cranio-orbital and petroclival meningiomas and involves the symptoms of affected outer skull base, marked cosmetic defects, and psychoemotional distress in a large number of patients. Orbitosphenopetrosclival meningiomas originate in the cavernous sinuses and medial parts of sphenoid bone wings. As tumor grows, it spreads into the orbit and the clival area, followed by dissemination to the infratemporal and pterygopalatine fossae, the nasopharynx, and the posterior cranial fossa. The large size of orbitosphenopetrosclival meningiomas, their significant spreading over the cranial base, and localization near the critical neurovascular structures result in a high rate of surgical and neurological complications and limit the degree of admissible resection. Prevention of liquororhea, the most frequent and dangerous postoperative complication, requires a thorough plastic reconstruction of the skull base defect. The scheduled nonradical resection enables one to eliminate such clinical manifestations as the exophthalmus, pain syndrome, eyelid edema, chemosis, and deformity of the temporozygomatic area. Palliative surgeries (plastic surgeries, resection of the temporomandibular joint in patients with strongly limited mouth opening) can be performed if it is impossible to completely or even partially resect the tumor (e.g., in case of multiple preceding surgeries and severe trophic disorders, limited potentiality for plastic closure of the defect). If a residual tumor is present, patients with orbitosphenopetrosclival meningiomas need to undergo adjuvant irradiation after the first surgery.

REFERENCES


Commentary

The article focuses on one of the most challenging problems in modern neurosurgery: therapy for disseminated craniofacial meningiomas. The authors were the first who isolated and described the group of orbitosphenopetroclival meningiomas, demonstrated the problems associated with managing this group of patients, and approximated to the description of the therapy standards.

The maximal possible tumor resection is accompanied by a high risk of postoperative complications due to the fact that the critical neurovascular structures are disturbed, which causes a chronic neurological deficit, patient’s disability, and even death. Subtotal resection allows one to reduce the risk of complications; however, the recurrence rate increases in this case. For this reason, the management needs to be supplemented with stereotactic radiation therapy or radiosurgery of tumor remnants. These procedures of conformed radiation are optimal in treating radically incurable craniofacial meningiomas that continue to grow after partial resection or the recurrent disseminated ones, since the high degree of suppression of tumor progression can be achieved, while the effect on the adjacent intact tissues is minimal.

Thus, treatment of the group of patients (that was formed within several decades) with tumors of mostly orbitosphenopetroclival localization who had been subjected to nonradical surgery is an extremely challenging task even at the most advanced neurosurgical centers. In this situation, it is reasonable to use the combination of all possible techniques and to use the palliative surgery aimed at maintaining the vital functions (vision preservation, maintaining nasal breathing and mouth opening, prevention of intracranial hypertension, and arrest of the pain syndrome) more widely in patients with a long-term manifestation and significant progression of the tumor.

The adequate and sequential use of all possible modern methods for diagnostics and therapy together with the sparing approach to patients can preserve and lengthen their lives, ensure better social adaptation and higher quality of life.

This study is well-exemplified; its topicality and novelty both in Russian and global practice is evident.

V.L. Puchkov (Moscow)
The outcomes of surgical management of vestibular schwannomas (VS) have attained a qualitatively new level over the past 15 years. These patients typically received treatment at specialized neurosurgical centers, where the surgical intervention for total resection of VS is performed on a regular basis by highly qualified surgeons, while the intraoperative monitoring is fine-tuned and perfect in technical terms. This fact has determined the fundamental changes in the outcome of surgical treatment. Anatomical preservation of the facial nerve (FN) in the overwhelming majority of patients (even with large and giant VS) is currently is the rule rather than the exception. Meanwhile, postoperative facial nerve dysfunction remains a significant functional loss or a predicted disorder, which frequently requires additional surgical correction. According to M. Samii et al. [14], the rate of this complication in large follow-up series after the resection of VS ranges from 3 to 19%. Mimic facial paresis resulting from facial nerve dysfunction is the primary reason of severe corneal complications associated with dysfunction of lacrimation, as well as severe psychoemotional disorders. Treatment of mimic paralysis is one of the most complicated problems in reconstructive surgery and frequently requires the multidisciplinary approach to be used. The modern algorithms of medical care for patients with dysfunction of mimic muscles is a combination of surgical methods with pharmacotherapy and physiotherapeutic muscle training procedures [2, 7].

Cross-neuroplasty methods are used to revive mimic facial muscles. Cross-neuroplasty of FN with the hypoglossal nerve [1–3, 15] has been used most frequently, although the accessory nerve was originally used as the donor nerve. VII-XI cross neuroplasty was performed by Drobnik in 1879 and by Faure in 1898. In 1903, one of the founders of modern neurosurgery H. Cushing conducted a neuroplastic surgery and provided a detailed description (for each day) of restoration of facial muscle function [5]. The publications that can be for the analysis contain few studies devoted to the assessment of long-term outcomes of facial nerve neuroplasty using accessory nerve among [6, 9].

This study was aimed at assessing the effectiveness of rehabilitation of mimic facial muscles by anastomosis of nerves VII–XI using modern scales for thorough analysis.
of the neurological status and assessment of the outcomes. The results of FN cross neuroplasty using the accessory and hypoglossal nerves were also compared based on the literature data.

**Material and Methods**

During 1998–2011, 20 patients underwent cross neuroplasty of facial nerve (FN) by the main trunk of accessory nerve. Patients were within the age range of 37–73 years (51.8 years in average). The average follow-up was 4.65 years (1–10 years). At baseline, all patients had total function loss of FN after excision of VS. Patients with total loss of anatomical integrity of the nerve and patients in whom the anatomical integrity was retained but the FN did not function 8 months after the tumor had been resected (internal axonotmesis) were included in the study. The interval between function loss and surgery was 1–8 months (4.7 months in average). Six patients had trigeminal nerve dysfunction. During the postoperative period, 12 patients underwent a 1-year course of integrated exercises for mimic and shoulder girdle muscles combined with transcutaneous electrostimulation of facial muscles. Video of the standard motion of facial and shoulder girdle muscles was recorded in all patients; thus, the functional status of each patient was assessed by a physician who did not participate in the surgery. Each patient was assessed by the clinical scales House–Brackmann Facial Grading System (HB) and Yanagihara system (YS) to estimate the extent of mimic paresis [13]. Sunnybrook Facial Grading scale (SFG) was used to assess facial symmetry and synkineses [17]. Self-assessment questionnaire Facial Disability Index (FDI) [18] was also used. The original questionnaire, Shoulder Disability Index (SDI) including 4 questions, was used for self-assessment of a denervated shoulder segment (the maximum score 100) (**Table 1**).

**Table 1. Shoulder Disability Index questionnaire**

<table>
<thead>
<tr>
<th>Question</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. How much difficulty do you have lifting your right (left) arm?</td>
<td></td>
</tr>
<tr>
<td>A. No difficulty</td>
<td>5</td>
</tr>
<tr>
<td>B. Little difficulty</td>
<td>4</td>
</tr>
<tr>
<td>C. Moderate difficulty</td>
<td>3</td>
</tr>
<tr>
<td>D. Very difficult</td>
<td>2</td>
</tr>
<tr>
<td>E. No, for other reasons</td>
<td>1</td>
</tr>
<tr>
<td>2. How much does the weight of loss of your right (left) shoulder bother you?</td>
<td></td>
</tr>
<tr>
<td>A. No difficulty</td>
<td></td>
</tr>
<tr>
<td>B. Little difficulty</td>
<td></td>
</tr>
<tr>
<td>C. Moderate difficulty</td>
<td></td>
</tr>
<tr>
<td>D. Very difficult</td>
<td></td>
</tr>
<tr>
<td>E. No, for other reasons</td>
<td></td>
</tr>
<tr>
<td>3. How much difficulty do you have making a simultaneous movement with your right (left) half of the face and right (left) shoulder?</td>
<td></td>
</tr>
<tr>
<td>A. No difficulty</td>
<td></td>
</tr>
<tr>
<td>B. Little difficulty</td>
<td></td>
</tr>
<tr>
<td>C. Moderate difficulty</td>
<td></td>
</tr>
<tr>
<td>D. Very difficult</td>
<td></td>
</tr>
<tr>
<td>E. No, for other reasons</td>
<td></td>
</tr>
<tr>
<td>4. To what extend does the pain in your right (left) shoulder bother you?</td>
<td></td>
</tr>
<tr>
<td>A. No difficulty</td>
<td></td>
</tr>
<tr>
<td>B. Little difficulty</td>
<td></td>
</tr>
<tr>
<td>C. Moderate difficulty</td>
<td></td>
</tr>
<tr>
<td>D. Very difficult</td>
<td></td>
</tr>
<tr>
<td>E. No, for other reasons</td>
<td></td>
</tr>
</tbody>
</table>

**Calculation of the integral shoulder disability index**

\[
\text{INDEX} = \frac{\text{Total score} \times 100}{\text{the number of questions answered} \times 4}
\]

The maximum total score for 4 questions = 20

\[
\text{SDI} = 100
\]
The statistical analysis was carried out using Statistica for Windows software (version 5.5). The probability \( p<0.05 \) was regarded as significant in the 95% confidence interval.

**Results**

Four patients (20%) recovered the FN function up to HB II; 11 (55%) patients, up to HB III, and 5 (25%) patients, up to HB IV–V. Thus, good outcome (HB II–III) was attained in 75% of patients.

The average YS score was 27.5±4.06; the average SFG score was 71.1±9.38. The average FDI self-assessment score was 143.75±22.82; the average SDI was 69.06±22.16 (Table 2).

All the acquired data were statistically analyzed and compared using Spearman’s rank correlation coefficient.

Strong correlation \((r=−0.72, \ p<0.001)\) was found between the YS and SFG magnitudes after surgery (Table 3). It should be mentioned that there is moderate correlation for assessment of the integral score for these scales; whereas no correlation was observed between the degree of synkinesis and the YS score. This can be attributed to the fact that the YS scale does not assess the synkineetic movements of facial muscles, while they are one of the key components of the disturbance of psychoemotional state in patients.

The correlation between the total FDI and SDI \((r=0.56, \ p<0.001)\), moderate correlation with the FDI social subscale score, and no correlation with the FDI physical functioning subscale (which includes questions concerning the function of facial muscles) were obtained (Table 4). The FDI index is a commonly used tool with verified validity. One of the methods to verify validity of scales is to compare them to the already existing valid scales; i.e., the existence of correlation attests to the validity of the proposed original SDI scale.

The patients who performed exercises and received electrostimulation demonstrated better functional outcomes \((p<0.05)\).

**Discussion**

The best functional result in patients with the integrity of the intracranial segment of FN disrupted after the resection of VS and other cerebellopontine angle tumors can be achieved using the end-to-end nerve suture or intraneural insertion (e.g., using \(n. \ suralis\) trunk). However, these methods cannot be used in most cases, since the proximal segment of FN near the trunk exit is injured, while a suture cannot be put in this case because of technical limitations. It is also possible that the anatomical integrity of the FN is preserved, while the function is not restored 6 months after the surgery [2, 7]. Preference is given to the dynamic correction methods in this case; the method of choice is to use substitution cross neuroplasty. The static correction methods (myoplasty and tarsoplasty) can be used in addition to the dynamic ones. Accessory, hypoglossal, phrenic, and
glossopharyngeal nerves, as well as the trigeminal nerve branch leading to the mastication muscle and motor branches of cervical plexus, can be used as donor nerves. Nevertheless, one needs to understand that the use of each of the nerves listed above has its own advantages and drawbacks, since the donor nerve function is eventually lost, while ensuring partial restoration of the function of mimic facial muscles.

### Comparison of the outcomes of neuroplastic surgeries using nerves XII and XI

In a series of neuroplastic surgeries of FN using hypoglossal nerve performed by J. Conley and D. Baker (137 patients) [4], the authors observed facial muscle hypertonicity in 78% of patients; articulation and swallowing disorders were observed in 16% of patients. M. Pensak et al. [16] reported difficulties associated with food intake in 74% of patients and invalidization caused by this dysfunction in 21% of patients. P. Hammerschlag [8] reported speech and swallowing disorders in 45% patients after VII–XII cross neuroplasty. After this surgery, patients have conjugate movements of facial muscles associated with tongue movements. Despite this statistics, most authors assess the results of using this method to be positive. The FN function after the surgery corresponds to HB III in 60% of patients, which is considered to be a "good" outcome. Reinnervation takes place within the period of 4–12 months.

Cross neuroplasty of the FN with the accessory nerve results in denervation of the trapezius and sternocleidomastoid muscles, concomitant atrophy and asymmetry of the shoulder, and conjugate shoulder and face movements (in case of successful reinnervation). Nevertheless, one needs to understand that the use of the accessory nerve has its own advantages and drawbacks, since the donor nerve function is eventually lost, while ensuring partial restoration of the function of mimic facial muscles and the movement of the shoulder joint. Nevertheless, one needs to understand that the use of the accessory nerve has its own advantages and drawbacks, since the donor nerve function is eventually lost, while ensuring partial restoration of the function of mimic facial muscles and the movement of the shoulder joint. Nevertheless, one needs to understand that the use of the accessory nerve has its own advantages and drawbacks, since the donor nerve function is eventually lost, while ensuring partial restoration of the function of mimic facial muscles and the movement of the shoulder joint.

<table>
<thead>
<tr>
<th>Method</th>
<th>Author, year</th>
<th>Number of cases</th>
<th>Restoration of the FN function (HB scale), %</th>
<th>XII – tongue hemiatrophy (%)</th>
<th>XI – shoulder atrophy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>XII</td>
<td>J. Conley, D. Baker (1979) [4]</td>
<td>137</td>
<td>0</td>
<td>65</td>
<td>17</td>
</tr>
<tr>
<td>XII</td>
<td>M. Pensak et al. (1986) [16]</td>
<td>61</td>
<td>0</td>
<td>42</td>
<td>10</td>
</tr>
<tr>
<td>XII</td>
<td>Donzelli et al. (2003)</td>
<td>3</td>
<td>0</td>
<td>33</td>
<td>0</td>
</tr>
<tr>
<td>XI</td>
<td>H. Cushing (1903) [5]</td>
<td>1</td>
<td>0</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>XI</td>
<td>Thulin, Petersen, Granholm (1964)</td>
<td>18</td>
<td>0</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>XI</td>
<td>L. Hirsh, F. Murtagh (1978) [9]</td>
<td>14</td>
<td>0</td>
<td>57</td>
<td>7</td>
</tr>
<tr>
<td>XI</td>
<td>Yu. A. Shulyev et al. (2012)</td>
<td>20</td>
<td>20</td>
<td>55</td>
<td>25</td>
</tr>
</tbody>
</table>

Note: *Only after resection of VS.

### Table 5. Comparison of the outcomes of XII–VII and XI–VII cross neuroplasty

<table>
<thead>
<tr>
<th>Method</th>
<th>Author, year</th>
<th>Number of cases</th>
<th>Restoration of the FN function (HB scale), %</th>
<th>XII – tongue hemiatrophy (%)</th>
<th>XI – shoulder atrophy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>XII</td>
<td>J. Conley, D. Baker (1979) [4]</td>
<td>137</td>
<td>0</td>
<td>65</td>
<td>17</td>
</tr>
<tr>
<td>XII</td>
<td>M. Pensak et al. (1986) [16]</td>
<td>61</td>
<td>0</td>
<td>42</td>
<td>10</td>
</tr>
<tr>
<td>XII</td>
<td>Donzelli et al. (2003)</td>
<td>3</td>
<td>0</td>
<td>33</td>
<td>0</td>
</tr>
<tr>
<td>XI</td>
<td>H. Cushing (1903) [5]</td>
<td>1</td>
<td>0</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>XI</td>
<td>Thulin, Petersen, Granholm (1964)</td>
<td>18</td>
<td>0</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>XI</td>
<td>L. Hirsh, F. Murtagh (1978) [9]</td>
<td>14</td>
<td>0</td>
<td>57</td>
<td>7</td>
</tr>
<tr>
<td>XI</td>
<td>Yu. A. Shulyev et al. (2012)</td>
<td>20</td>
<td>20</td>
<td>55</td>
<td>25</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Method</th>
<th>Author, year</th>
<th>Number of cases</th>
<th>Restoration of the FN function (HB scale), %</th>
<th>XII – tongue hemiatrophy (%)</th>
<th>XI – shoulder atrophy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>XII</td>
<td>J. Conley, D. Baker (1979) [4]</td>
<td>137</td>
<td>0</td>
<td>65</td>
<td>17</td>
</tr>
<tr>
<td>XII</td>
<td>M. Pensak et al. (1986) [16]</td>
<td>61</td>
<td>0</td>
<td>42</td>
<td>10</td>
</tr>
<tr>
<td>XII</td>
<td>Donzelli et al. (2003)</td>
<td>3</td>
<td>0</td>
<td>33</td>
<td>0</td>
</tr>
<tr>
<td>XI</td>
<td>H. Cushing (1903) [5]</td>
<td>1</td>
<td>0</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>XI</td>
<td>Thulin, Petersen, Granholm (1964)</td>
<td>18</td>
<td>0</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>XI</td>
<td>L. Hirsh, F. Murtagh (1978) [9]</td>
<td>14</td>
<td>0</td>
<td>57</td>
<td>7</td>
</tr>
<tr>
<td>XI</td>
<td>Yu. A. Shulyev et al. (2012)</td>
<td>20</td>
<td>20</td>
<td>55</td>
<td>25</td>
</tr>
</tbody>
</table>

Note: *Only after resection of VS.
linkage to the cortical centers is lost [10]. Facial symmetry at rest and complete closure of the palpebral fissure was attained in most patients, which corresponds to the scale HB III–IV. Arbitrary movements of certain groups of mimic muscles and shoulder-girdle symmetry are the potentially attainable result. This result can be attained provided that a patient is highly motivated, since it requires regular and tenacious exercises for mimic and shoulder-girdle muscles.

Assessment tools and subjectivism

A researcher has a sufficiently large set of scales and questionnaires supplementing each other at his disposal. However, only the unilateral assessment by a physician using the HB scale is employed in most studies, while no assessment of the outcomes is performed by patients. T. Kunihiro et al. [12] used HB and YS scales for assessment by physicians, while the patients were offered to self-assess the condition of their face according to a 100-point scale. The authors revealed no correlation between the assessments of the FN function performed by physicians and patients. M. Ikeda et al. [11] used the HB and YS scales together with questionnaires to find a correlation between the responses obtained from physicians and patients; however, this correlation varied significantly, thus attesting to the importance of the subjectivism factor. For instance, 20–30% of patients who were assessed as completely cured by the physicians complained of disturbed movements of facial muscles in the questionnaires.

Special attention should be paid to the use of specialized scales after substitution neuroplasty to assess the function of a deververated segment. Oral-Pharyngeal Disability Index was used after VII–XII cross neuroplasty in several studies [13]. However, we found no scale to assess the function of the shoulder girdle after the accessory nerve loses its function in the literature available for analysis, which served as an incentive to elaborate a specialized assessment tool, the Shoulder Disability Index.

Conclusions

Results of cross neuroplasty of FN using AN are compatible with those obtained using other neuromuscular techniques and improve patients’ quality of life. This procedure is acceptable for rehabilitation of FN function after skull base surgery. The best functional result can be attained by combining this technique with subsequent training of mimic muscles. The main problem associated with the assessment of mimic muscles is subjectivism; that is why clinical scales and self-assessment questionnaires need to be used to ensure reliable results. After cross neuroplasty was performed, the denervated shoulder segment should be assessed using a specialized scale.

REFERENCES

This study performed by skilful neurosurgeons at a high level using various common tools for assessing the extent of mimic muscle disability has demonstrated again that neurosurgeons and patients have different attitudes toward the final outcome of treatment. After neurosurgeons had performed a sophisticated surgery for brain, saved patient’s life and improved his or her health, they treat the long-term effects of facial muscle dysfunction in a rather lenient manner as they consider that a good result is when most patients can perform certain mimic movements. However, after the patient recovers from initial anxiety, he or she wants to be completely rehabilitated, in particular, if his or her occupation is associated with working with people or if he or she is young.

The problem of restoration of the mimic muscle function can be successfully solved without any additional interventions on the tongue or shoulder-girdle muscles. There is a large number of well-developed procedures that the authors either do not know about or have not assessed them properly. These patients eventually admit to a plastic surgeon; however, it is often too late. I have not seen a patient who would be operated by neurosurgeons according to the procedures described above without obtaining a shoulder or a tongue dysfunction. At this point, the mimic movements cannot be corrected: to do so, one needs to cut the sutured nerve, isolate the facial nerve trunk again, connect it to the facial nerve at the unaffected half of the face, and additionally use a motor nerve (mylohyoid, masseteric, or the side-to-end insertion of the hypoglossal nerve). Indeed, it is easier to tell a patient that some movements had been preserved and there hardly is any sense in performing the procedure again.

It has been proven today that synkinesis and the thirteenth Bechterew’s symptom (which are considered to be inevitable effects of suturing another nerve by the authors of this article) can be successfully cured using a complex of special measures. It has been elucidated today symmetric movements of facial muscles cannot be attained without performing cross neuroplasty with the healthy facial nerve.

The carefully dosed injection of Botox, stimulation on devices designed especially for this purpose, and teaching a patient to do special mimic exercises need to be included in the complex management of these patients. Even the natural blink reflex can be attained nowadays. Even a slight dysfunction of mimics, the loss of function of a single muscle, is a tragedy for many people.

I have no objection to this article being published, but I would like to have my commentary published as well. Either a surgeon specializing in facial nerve surgery who would know all the modern methods needs to be trained at a large neurosurgical department or a patient needs to be referred to the specialists in the nearest time after the nerve intersection surgery (especially since they are covered by the quota system).

I am not giving any comments to the reference list; it is self-explanatory.

A.I. Nerobeev (Moscow)
A Comprehensive Study of Early Outcome (at the time of Discharge from the Hospital) after Lumbar Discectomy for Degenerative Spine Disease

M.K. SHARMA, L.V. CHICHANOVSKAYA, V.A. SHLEMSKY

Tver State Medical Academy, Russia

**Objective:** To find out early outcomes after lumbar discectomy in patients with degenerative spine disease at discharge (10–12 days after surgery) from the hospital.

**Methods.** The study was performed on 50 patients who have undergone lumbar discectomy for degenerative disc/spine disease in their pre- and post-operative stages of treatment. The study included 50 patients, taking into account both anamnesis and postoperative follow-up data. The outcomes were evaluated using modified Oswestry Disability Index (ODI), Visual Analogue Scale (VAS), and location of pain.

**Results.** The study group consisted of 50 patients who completed the questionnaire in the pre- and post-operative period. The mean age of the patients (27 males and 23 females) was 50.0±2.1 years. The questionnaire contained questions about severity of pain (VAS), pain tolerance, well-being, walking, standing, sitting and sleeping. The data were compared in the pre- and post-operative stages; the differences were evaluated using the paired t-test. There was a significant difference in pain severity, walking, standing and sleeping among pre- and post-operative patients. 42% of patients noted a significant reduction of pain in the postoperative period. 48% of patients showed normalization of sleep without analgesics and hypnotics. About 72% of patients on the onset of the disease noted pain in both back and leg and 6% had only low back pain at the pre-operative stage. 52% of patients had no pain soon after surgery.

**Conclusion.** Most patients noted an improvement: the rapid reduction of pain and restoration of sleep without analgesics and hypnotics in the post-operative period.

**Keywords:** lumbar discectomy, DSD – degenerative spine disease, ODI – Oswestry Disability Index, VAS – Visual Analogue Scale.
sent to be included in the study). The exclusion criteria were as follows: unusual medical cases, severe tumor or cardiovascular diseases and spine disorders (injuries, etc.). The study was conducted before and after the surgical intervention (10–12 days after surgery) using questionnaire completion.

The modified Oswestry Disability Index was used to determine the pre- and postoperative outcomes. The questionnaire is a scale with questions regarding the social and demographic variables, pain severity (score 0–10), pain tolerance (score 0–5), well-being (score 0–3), walking ability (score 0–5), standing ability (score 0–5), sleep quality (score 0–5), and location of pain. VAS was used to provide visual assessment of pain in the studied cohort of patients.

The questionnaire used for postoperative assessment was the same as that used for preoperative assessment with two items added (changes in pain severity (score 0–5) and sleep without analgesics (score 0–5) in order to observe the positive outcomes.

The statistical analysis was performed using an applied software package for data processing SPSS version 18.0 (SPSS Inc., Chicago, IL, USA). The parametric data were expressed as the mean ± standard deviation. The paired t-test was used to reveal the differences for variables during the pre- and postoperative period.

**Results**

The questionnaires were completed by the patients both during the pre- and postoperative stages of the study. The questionnaire covered the questions regarding pain severity (VAS), pain tolerance, general well-being, walking and standing ability, and sleep quality. The responses obtained before and after the surgery were compared and evaluated using the paired t-test (Table 1). It is clear from Table 1 that there is significant difference in such variables as pain tolerance and walking, sitting, and sleeping ability in patients before and after surgery.

![Fig. 1. Degree of changes in pain intensity in patients under study during the postoperative period.](image1)

Score: 0 – pain rapidly becomes less severe; 1 – pain is instable but becomes less severe; 2 – pain slowly becomes less severe; 3 – pain becomes neither more nor less severe; 4 – pain gradually becomes more severe; 5 – pain rapidly becomes more severe.

![Fig. 2. Qualitative characterization of sleep (without using analgesic agents) in the postoperative period.](image2)

Score: 0 – my sleep has never been interrupted because of pain; 1 – my sleep is sometimes interrupted because of pain; 2 – I sleep less than 6 h because of pain; 3 – I sleep less than 4 h because of pain; 4 – I sleep less than 2 h because of pain; 5 – I cannot fall asleep because of pain.

| Table 1. Criteria of the assessment (score) of the early outcomes after discectomy (M±SD) |
|-------------------------------|------------------|------------------|-----------------|-------|
| **Index**                     | **Before surgery** | **After surgery** | **Change**      | **p** |
| Pain tolerance                | 2,9±1,4           | 1,4±1,4           | −1,5            | <0,001*|
| Well-being                    | 1,1±1,0           | 0,8±0,8           | −0,3            | 0,075 |
| Walking ability               | 2,7±1,6           | 1,7±1,4           | −1,0            | <0,001 |
| Standing ability              | 3,1±1,6           | 1,7±1,4           | −1,4            | <0,001 |
| Sitting ability               | 3,2±0,2           | 3,4±1,8           | 0,2             | 0,064 |
| Sleep                         | 2,3±1,7           | 0,7±0,9           | −1,6            | <0,001*|
| VAS                           | 7,1±2,1           | 2,9±2,3           | −4,2            | 0,048 |

Note. * Significant difference at p<0.001 in the paired t-test. The changes were calculated as the difference between score after and before surgery. The negative values indicate improvement for all the variables.
sleeping ability. The pain severity assessed by VAS score was lower at the postoperative stages, which is in agreement with the data obtained by O. Hagg et al. [5], who reported similar results in patients with spine disorders.

The early outcomes for location of pain were studied via cross tabulation. The results also demonstrated a significant reduction of back pain (in the lumbar region) and legs at the postoperative stages. Most patients reported the absence of back pain (in the lumber spine) at this stage. Some patients had marginal pain during the postoperative period. The study results coincide with the data obtained by J. Fairbank and P. Pynsent [4], who reported similar outcomes in patients with spine disorders.

Rapid pain arrest during the postoperative period was observed in 42% of patients, while only 2% of patients reported pain aggravation after treatment (Fig. 1). Sleep normalization was achieved in a significant number of patients (48%) without using analgesic and hypnotic agents. Only 4% of them reported reduced sleep duration (less than 6 h) because of pain (Fig. 2).

Cross-tabulation was performed to reveal the differences in early outcomes at the pre- and postoperative stages associated with location of pain. Approximately 72% of patients reported pain in the lumbar spine (back) and legs and 6% of patients reported back pain (in the lumbar spine) at the preoperative stage. 52% of patients reported no pain at the postoperative stage (Table 2).

**Discussion**

The early outcomes after lumbar discectomy in patients with degenerative spine disease at discharge from the hospital were assessed in this study. According to the results, most patients reported an improvement in their condition after surgery. The questionnaires where the data on pain severity, well-being, general condition, and walking, sitting, and sleeping ability were compared for the pre- and postoperative periods attested to significant changes in these indices. These conclusions are in agreement with the data obtained by G. Waddell [12], which also attested to pain reduction in patients with the same pathological condition during the postoperative stages. The general improvement of condition during the postoperative stages was noted according to the data reported by the patients regarding their walking, sitting, and sleeping ability. The pain severity assessed by VAS score was lower at the postoperative stages, which is in agreement with the data obtained by O. Hagg et al. [5], who reported similar results in patients with spine disorders.

The early outcomes for location of pain were studied via cross tabulation. The results also demonstrated a significant reduction of back pain (in the lumbar region) and legs at the postoperative stages. Most patients reported the absence of back pain (in the lumbar region) at this stage. Some patients had marginal pain during the postoperative period. The study results coincide with the data obtained by J. Fairbank and P. Pynsent [4], who reported similar outcomes in patients with spine disorders.

The negative values are indicative of the improvement of all the variables. The early outcomes after lumbar discectomy in patients with degenerative spine disease at discharge from the hospital were evaluated in this study. The improvement (rapid reduction of pain syndrome and sleep normalization without using analgesic and hypnotic agents) was noted in most patients during the postoperative period.

**Conclusions**

The outcomes of discectomy attest to the reduction of pain syndrome, sleep normalization, and improvement of the quality of patients' life. There are grounds for prognosing the positive dynamics in these patients during the long-term period after the surgery, including the restoration of the deficit and the lost functions, as well as returning of the patients to their habitual daily and professional activity.

**REFERENCES**

When assessing the postoperative outcomes in patients with degenerative and dystrophic lesions of the spine, much attention is currently paid to scales and questionnaires, which allow one to make the subjective complaints of a patient objective. Most foreign case-based studies that allow one to assess the efficiency of a surgical treatment technique are based on the results obtained using these scales. Furthermore, the use of scales is economically profitable, since the most economically beneficial surgical techniques can be singled out. It should be mentioned that the validity of using foreign social scales (e.g., Oswestry) to evaluate the efficiency of spine surgeries is disputable, since they do not comply with the living standards of Russian patients and many questions in this questionnaire resulting from unadapted translation remain unclear for our patients.

The article being reviewed is devoted to quite an urgent problem: methods for assessing the early postoperative outcomes and quality of life in patients operated on for degenerative and dystrophic pathology of intervertebral discs in the lumbosacral spine and actually demonstrate the use of these scales to assess the efficiency of surgical treatment. The study included 50 patients, in whom the dynamics of Oswestry and Visual Analogue Scale (VAS) indices and location of pain were studied on day 10–12 after surgery against the preoperative level. The common assessment criteria (general health questionnaire SF-36 that has undergone representative clinical trials for Russian patients and is commonly used in the European countries and questionnaire MigAn elaborated in Russia and adapted for Russian patients) were not used in this study. The authors have drawn a conclusion that the pain syndrome was arrested in 52% after the surgery; sleep was normalized in 48% of patients without using analgesic and sedative agents; 2% of patients reported aggravation of pain. Neither comparison of the efficiency of different surgical procedures nor comparison with the efficiency of the conservative method was performed in the study.

The authors reasonably mention the great significance of specialized scales and questionnaires for the modern spinal surgery, which is characterized by a great variety of surgical techniques. The scales selected for the study are reliable; their validity has been confirmed in a number of foreign studies. In addition, the resulting data were statistically analyzed using paired t-test and the cross tabulation method. These methods give grounds for objectively assessing the complaints of patients in a sample under study and for following up their postoperative dynamics. The thoroughness of studying the pre- and postoperative status both in terms of the pain syndrome and limitation of physical activity and in terms of the social and emotional status using these questionnaires allows one to obtain a comprehensive idea (expressed numerically) about the dynamics of the set of symptoms after discectomy.

The drawbacks of this study is that the authors did not make allowance for a number of parameters that are significant for the assessment (e.g., the features of the neurological status in the pre- and postoperative period; topographicoanatomical features of the intervertebral disc herniation in a certain patient, surgical approach (microsurgical, endoscopic resection, volume of bone resection), etc.).

Nevertheless, the resulting data allows one to assess the efficiency of surgical treatment of disc herniation in the lumbosacral spine. The results are reliable and compatible with the conclusions in the similar studies conducted by foreign researchers. It should be emphasized that this study was carried out at a regional medical center. I would like to wish the authors and their colleagues further scientific accomplishments.

A.O. Gushcha (Moscow)
Intraparenchymal Brainstem Schwannomas: Report of Three Cases and Literature Review


N.N. Burdenko Neurosurgical Institute, Russian Academy of Medical Sciences, Moscow, Russia

We report three patients with intraparenchymal brainstem schwannomas that were confirmed by surgery and pathological examination: tumors originated from the midbrain parenchyma, the dorsal aspect of the pontomedullary junction and the medulla oblongata, respectively. According to the published data [1, 2, 6, 9, 10, 13, 19, 25, 26], only 10 cases of intraparenchymal schwannomas of brainstem have been described. This study reports three cases of brainstem schwannomas with the diagnosis confirmed by the surgery and histological data. The tumors differed in terms of localization inside the brainstem: the mesencephalic tegmentum was affected in one case, while the dorsal aspect of the pontomedullary junction and medulla oblongata were affected in the other two cases. The difference in age and duration of disease presentation may be indicative of different mechanisms of formation of these tumors.

Keywords: schwannoma, brain stem.

Case description

Case 1

In 2000, seven months before admission to the hospital, a 44-year-old woman noticed left-sided facial numbness, which subsequently spread to the entire left half of the body. The somatic status was regular. Neurological bilateral nystagmus was observed. The surface sensitivity to pain and temperature near the left trigeminal nerve, in the left side of the body, in the left upper and lower limbs was reduced. Left pyramidal syndrome was observed. Ophthalmoscopic examination revealed no eyeground congestion. MRI detected a cystic neoplasm accumulating contrast in the dorsal aspect of the mesencephalic tegmentum (right side). Cystic glioma of the brainstem was preliminarily diagnosed according to this clinical and roentgenographic pattern (Fig. 1, a–c).

Surgery and postoperative period. The patient in the sitting position was subjected to suboccipital craniotomy and lateral infratentorial supracerebellar approach to the tumor. After the arachnoid sheath had been dissected, the intact right trochlear nerve in its quadrigeminal segment was visualized. The surface of the midbrain in its dorsolateral portion was slightly distorted and was of grayish color. Where the amount of changes was the greatest, the surface layer of the brain tissue was punched with branches of thin forceps to reveal a gray cystic tumor. The pathological tumor localized in brain parenchyma and was completely resected. An emergency histological test detected a schwannoma, which was subsequently confirmed by the final histological examination (Fig. 2).

No complications were observed during the postoperative period. By the discharge from the hospital on day 9...
after the surgery, the patient has noted regression of facial numbness. The ophthalmological examination detected no aggravation. MRI performed 1 month after the surgery demonstrated no tumor remnants (Fig. 1, d, e).

Case 2

A 22-year-old patient. In 2010, three months before the surgery, an intense headache, diplopia emerged. Unsteadiness in walking, weakness of facial muscles on the left side, taste change, and left-sided hearing deterioration have emerged and started to become more severe. The somatic status was regular. The neurological status included the insufficiency of the abducent nerve on the left side; reduced surface, pain, and temperature sensitivity in the innervation area of the left trigeminal nerve. Left-sided peripheral paresis of the facial nerve (grade 3

Fig. 1. MRI scans of a 44-year-old female patient. Case 1.

a–c — preoperative MRI scans: contrast-accumulating cystic tumor localized in the right portion of the dorsal midbrain.

Fig. 1 continued on the next page
according to the House–Brackmann grading system) and loss of taste within the front 2/3 portion of the tongue were observed. Signs of sensorineural hearing loss in the left ear and the reduced pharyngeal reflex on the left side were also revealed. Ophthalmoscopic examination revealed congestion of the discs of optic nerves. A contrast-accumulating cystic tumor of the pons cerebellar and medulla oblongata spreading to the fourth ventricle was detected by MRI (Fig. 3, a–c). Brainstem glioma was preliminarily diagnosed according to the clinical and roentgenographic pattern.

Surgery and postoperative period. The patient in the sitting position was subjected to suboccipital craniotomy. After the cerebellar tonsils had been separated, the drastically deformed surface of the rhomboid fossa and gray tumor destroying the ependyma were imaged. Tu-
mor resection was started in the area where the changes in brainstem were maximal. During the surgical procedure it became clear that the tumor completely localizes in the brain parenchyma and has no connection to the basal cisterns. Since the resection of the caudal portion of the tumor results in intense hemodynamic reactions, resection of these areas was limited. Schwannoma was revealed by emergency biopsy, which was subsequently confirmed by the final histological examination (Fig. 4). Since tumor remnants were present near the fourth ventricle outlets, a silicon stent (starting from the great occipital cistern, running through the Sylvian aqueduct and ending in the third ventricle) was mounted in order to prevent the development of occlusion hydrocephalus.

No complications were observed in the postoperative period. By the time of discharge from the hospital (postoperative day 8), the patient noted that the weakness of facial muscles reduced. Ophthalmological examination revealed regression of congestion of the discs of optic nerves. An MRI performed 3 months after the surgery detected tumor remnants in the caudal portions of the brainstem and the fourth ventricle; the reduced size of the ventricular system attested to stent functioning (Fig. 3, d–f). The patient was followed up by dynamic MRI: the control MRI performed 1 year after

---

**Fig. 3. MRI scans of a 22-year-old female patient. Case 2.**

a–c – preoperative MRI scans: contrast-accumulating tumor of the dorsal aspect of the pontomedullary junction with the cystic component localized in the fourth ventricle.

*Fig. 3 continued on the next page*
the surgery demonstrated that the size of the tumor remnants was unchanged.

Case 3

A 23-year-old patient. In 2011, two months before the surgery, clinical manifestations of the disease emerged: weakness of the right limbs and numbness of the right half of the body (including face) gradually developed. One month after the onset of the disease, patient’s tone of voice changed and choking when taking meals started. By the time the patient was hospitalized, the clinical presentation of the disease included symptoms on the left half of the caudal brainstem: bulbar disorders, nerve XII insufficiency (tongue deviation to the left side), pyramidal hemisindrome (muscular strength in the right limbs reduced to score 4; accelerated tendon reflexes) and afferent hemisindrome (hemi-hypesthesia for pain on the right half of the body, including face; disturbance of sensation arising from joints and muscles on the right half of the body up to the ankle and radiocarpal joints). MRI detected a bulk solid cystic tumor of the medulla oblongata with the contrast agent being accumulated in the solid portion of the tumor (Fig. 5). The patient was preliminarily diagnosed with
astrocytoma of the medulla oblongata and subjected to surgical treatment.

Surgery and postoperative period. Severe deformity of the left half of the medulla oblongata was imaged during the surgery through midline suboccipital craniotomy. At this spot, the floor of the fourth ventricle was protruding; the midline was drastically shifted to the right; however, no ependymal changes were observed. In this connection, an approach through the left cerebromedullary fissure to the lateral surface of medullar oblongata was performed, where a cystic tumor could be seen through the depleted medullary substance. At the site where the greatest changes were observed (in the projection of area retroolivaris), the medullary substance was perforated with the tips of thin anatomical forceps to open the cystic tumor containing yellow opalescent fluid at a depth of less than 1—2 mm. The tumor was represented by a gray intraparenchymatous solid nodular lesion with dense structure, which had clear borders with the adjacent brain tissue. The nodular lesion was step-by-step fragmented, separated from the medullary substance, and resected. The histological and immunohistochemistry tests of biopsy samples revealed neurinoma with strong expression of S-100 protein and a low Ki-67 labeling index (below 2%). Aggravation of the bulbar disorders was observed after the surgery, making it necessary to perform puncture tracheostomy and to feed the patient through a tube in the early postoperative period. One month after the surgery, regression of the bulbar lesions that had aggravated immediately prior to the surgery was observed. No loss of sensation in the right half of the body was observed any longer. No tumor remnants were detected by MRI 4 months after the surgery.

Discussion

The histogenesis of intraparenchymal schwannomas is abnormal by definition, since the parenchyma of the brain and spinal cord in the normal condition contains no Schwann cells. The hypotheses explaining schwannoma formation can be conventionally subdivided into the ones assuming the disembyrogenetic origin of schwannomas and the hypotheses not associated with embryogenesis disturbance. The latter ones are based on the fact that perivascular nerve fibers penetrating to the CNS parenchyma contain Schwann cells and myelin [20]. Some researchers [1] believe that intramedullary schwannomas can develop from these cells as a result of proliferative reaction to tissue lesion; in particular, the incidence of Schwann cell proliferation foci (schwannosis) in spinal cord increases with age and in patients with diabetes.

Another potentiality for the formation of intraparenchymal schwannomas is the dorsal root entry zone (the transitional zone where nerve fibers lose myelin when penetrating through the pia). The tumor may originate from this area, grow in the central direction along the root followed by intramedullary penetration [12].

According to the disembyrogenetic hypothesis, abnormal Schwann cells develop from mesenchymal pial cells of the brain parenchyma [5] or from ectopic cells of the neural crest [18], which may underlie the phenomenon of multiple intraparenchymal schwannomas [9, 15].

Abnormal intramedullary peripheral nerve fibers observed in patients with spinal cord pathologies can also be associated with the histogenesis of intraparenchymal schwannomas [4, 8, 16]. Nonetheless, despite
the fact that abnormal nerve fibers can occur in patients with myelopathy of different etiology, the disembyroge
netic mechanism of their formation cannot be unam-
biguously eliminated from consideration.

The mean age of patients with intraspinal schwan-
nomas was found to be 44 years against 22 years in pa-
tients with intracranial tumors [2, 3, 19, 22]. Proceeding
from this difference in age of the disease onset, an as-
sumption has been made that the formation of intrace-
rebral schwannomas in young patients is based on the
disembyrogenetic mechanism, as opposed to adult pa-
tients with intraspinal tumors, where a significant role
is played by non-disembyrogenetic factors [2, 3, 19]. As
they localize in the transitional zone between the intrac-
ranial and intraspinal space, brainstem schwannomas
may have either of disembyrogenetic or non-disemby-
rogenetic mechanism of formation. However, according
to the published data, elderly people are the predomi-
nant group among patients with parenchymal brainstem
schwannomas (see Table).

Taking into account the young age of the patients
with pontomedullary schwannoma and schwannoma of
the medulla oblongata, the histogenesis of tumors in
these cases can be attributed to the disembyrogenetic
factors, since hyperplasia of perivascular Schwann cells
or formation of abnormal nerve fibers resulting from
brain lesion would have required a long-term premorbid
period, not to speak of the time required for tumor for-
mation. On the other hand, in the 44-year-old female
patient, the mechanism of tumor formation was most

Fig. 5. MRI scans of a 23-year-old female patient. Case 3.

a–c – preoperative MRI scans: contrast-accumulating tumor localizing in the parenchyma of medulla oblongata and having a cystic component.
likely to be non-disembryogenetic and was presumably associated with proliferation of Schwann cells in the entry zone of the trochlear nerve to the mesencephalon.

It should be mentioned that in one case the tumor was accompanied by occlusion hydrocephalus; the intense tumor infiltration in the brainstem made radical resection impossible. In turn, nonradical resection is the main reason behind progression of postoperative hydrocephalus (its frequency can be as high as 90% for surgical treatment of tumors of the posterior cranial fossa) [21, 24]; the average frequency is 40% [24]).

Stenting of the ventricular system at the stage of tumor resection allows one to prevent the development of occlusion hydrocephalus in postoperative period, thus eliminating the demand for additional surgical intervention for its correction [17]. When it is impossible to perform radical resection of the tumor blocking liquor circulation at the level of the fourth ventricle, stenting can be performed in order to prevent progression of hydrocephalus.

REFERENCES

The authors present 3 case reports for patients in which a tumor localized inside the brainstem parenchyma and showed no explicit association to the cranial nerves turned out to be the schwannoma. About 10 similar cases have been reported thus far. The histogenesis of these tumors has not been completely elucidated; the following mechanisms of formation of these tumors are proposed: 1) hyperplasia of Schwann cells in perivascular nerve fibers resulting from tissue lesion; 2) development from abnormal nerve fibers resulting from various brain pathologies; 3) centripetal growth of the schwannoma that was originally formed in the dorsal root entry zone; 4) ectopia of neural crest cells; and 5) development from mesenchymal pial cells of the brain parenchyma. The two latter mechanisms are disembryogenetic, which may cause the early age of patients with disease onset. The difficulties associated with surgical resection mostly arise from the proximity of the tumor to brainstem structures (in particular, medulla oblongata). It is reasonable to partially remove the tumor in this case, which was performed by the authors when performing a surgery in one of the patients. Taking into account the fact that these tumors may affect the fourth ventricle, nonradical resection may result in retention of occlusion hydrocephalus. The authors propose to use stenting of the liquor space to prevent dropsy in these cases.

V.A. Lazarev (Moscow)
The First Experience of Skull Base Defect Reconstruction Using Pedicled Buccal Fat Pad after Endoscopic Endonasal Resection of a Craniofacial Tumor

D.A. GOLBIN, N.V. LASUNIN

N.N. Burdenko Neurosurgical Institute, Russian Academy of Medical Sciences, Moscow, Russia

Background. Buccal fat pad (BFP) is widely used in maxillofacial surgery for closure of oroantral and oronasal defects. V.A. Cherekaev et al. were the first who described application of a pedicled BFP flap in reconstruction of anterior and middle skull base defects. This article focuses on a novel surgical technique: plastic closure of craniobasal defects via endonasal endoscopic approach.

Material and methods. We present a case of a 12-year old male patient with advanced juvenile angiofibroma who was operated endoscopically using biportal transnasal-transantral approach. After the removal of the tumor, the defect of anterior cavernous sinus was reconstructed by translocated pedicled BFP flap supported by a balloon catheter.

Results. No postoperative complications, such as cerebrospinal fluid nasal leakage were observed after withdrawal of the balloon catheter on the 4th day after surgery. The same day the patient was discharged in good condition.

Conclusions. The proposed technique is promising and advantageous as part of complex multilayer skull base defect reconstruction after resection of extra-intracranial mass lesions due to preserved vascular supply of BFP flap. The method is safe and associated with extremely low risk of complications. We hope that the described flap will be appreciated and will take its place within the range of plastic materials for reconstruction of skull base defects in endoscopic endonasal approach.

Keywords: skull base defect, reconstruction, buccal fat pad, endoscopic endonasal approach.

Buccal fat pad (BFP) is widely used in maxillofacial surgery to close oroantral and oronasal defects [5, 7, 11, 16]. V.A. Cherekaev et al. [2, 4] were the first who described application of a pedicled BFP flap in reconstruction of anterior and middle skull base defects. This article focuses on a novel surgical technique: plastic closure of craniobasal defects via endonasal endoscopic approach by harvesting a flap without any additional exterior or intraoral incisions.

Clinical case

12-year-old male patient S. diagnosed with predominantly left-sided disseminated craniofacial angiofibroma was admitted at the N.N. Burdenko Neurosurgical Institute on August 28, 2012. The disease started to manifest itself as stuffiness in nose 1 year before admission to hospital. A biopsy performed on June 19, 2012 detected juvenile angiofibroma. At admission, the clinical presentation of the disease included bilateral anosmia, obstruction of the nasal cavity, protrusion of the tumor from the left nostril, purulent discharge from the nasal cavity, recurrent hemorrhages, reduced vision to 0.3–0.4, distortion of the left half of the face because of edema, and left-sided conductive hearing loss. Computed tomography (CT) detected a large craniobasal angiofibroma spreading to the medial portions of the mesocranial fossa, in the area of the cavernous sinus (Fig. 1).

Endovascular embolization of afferent vessels from the maxillary and the ascending pharyngeal arteries on the left side and the maxillary artery on the right side using PVA microemboli was performed on September 4, 2012. Branches of the cavernous and ophthalmic segments of the left internal carotid artery that also participated in tumor blood supply were not embolized.

The endoscopic endonasal resection of disseminated craniofacial angiofibroma (predominantly on the left side) was performed on September 6, 2012. The biportal transnasal-transantral approach was used. First, the tumor was removed from the nasal cavity and the nasopharynx; next, it was removed from the sphenoid and cavernous sinuses. The next stage comprised luxation and removal of the tumor node from the infratemporal and the pterygopalatine fossae. At the final stage, the site of tumor origin (the base of the pterygoid process) was drilled. A defect of the medial sections of the base of mesocranial fossa in the anteroinferior sections of the cavernous sinus was formed after the angiofibroma had been removed. A pedicled buccal fat pad flap was relocated to close the defect (Fig. 2). An expandable balloon catheter was used to fix the flap near the defect.

The postoperative period was uneventful. The balloon catheter was removed on day 4 after surgery; no
Fig. 1. Preoperative contrast-enhanced CT scan.
The tumor occupies the left half of the nasal cavity, nasopharynx, the medial sections of the supermaxillary sinus, the pterygopalatine and infratemporal fossae and disseminates to the anterosuperior sections of the cavernous sinus, eye socket, and the optic canal.

Fig. 2. Intraoperative photograms at the final stage of the surgery.
A – removal of BFP from its bed; B – placing a pedicled BFP flap on the defect of the mesocranial fossa; C – fixation of the BFP flap using an expandable balloon catheter. Endoscope 0°, left side. 1 – sphenoid sinus; 2 – nasopharynx; 3 – floor of the nasal cavity; 4 – nasal septum; 5 – defect of the medial wall of the maxillary sinus; 6 – BFP flap; 7 – balloon catheter; 8 – mucous membrane of the lateral nasal wall.
signs of liquorrhea nasalis were observed. Nasal breathing was normalized; vision in the left eye recovered to 1.0; facial edema regressed. Angiofibroma diagnosis was confirmed by histological analysis. The child was discharged on the 4th day after the surgery in satisfactory condition. Figure 3 shows the postoperative CT scans.

Discussion

Reconstruction of skull base defects when resecting tumors through the endoscopic endonasal approach is one of the first-priority problems of modern neurosurgery. The reconstruction of the defect is aimed at closing the subdural space and completely isolating it from the sinonasal tract; preserving the neurovascular structures and visual functions [14]. The surgical procedure of closing the cranial cavity is based on complex multilayer plastic reconstruction using various materials [13].

P. Cappabianca et al. [3] claim that the ideal material for reconstruction of the defect of the cranial base when conducting transsphenoidal surgeries has to comply with the following requirements: inertness, simple adaptability of its shape and contours, easy mounting and positioning, and compatibility with CT and MR imaging.

A. Kassam and C. Snyderman (Clinics of Endoscopic Skull Base Surgery) [12, 13, 17] analyzed a large series of surgeries to elaborate a new concept of multilayer plastic reconstruction of the skull base defect after the intervention performed through the extended endonasal transsphenoidal approach. This procedure made it possible to reduce the rate of postoperative liquorrhea by 50%.

The first layer of plastic surgery included the fragment of collagen matrix (such as Duragen) that was placed between the brain and the dura mater. The matrix is covered by the second (epidural) layer, which is supposed to consist of a single tissue fragment and cover the entire bone defect. The third layer of plastic surgery includes obliteration of the sinuses with an adipose autograft, which facilitates vascularization and tissue healing and maintains pressure minimizing the risk of migration of the former two layers. Fibrin adhesive is used as the final, fourth (barrier), layer.

A balloon catheter is used to prevent the migration of plastic material and fistula formation (e.g., Foley catheter that is removed 3–5 days after surgery without any risk of injuring the plastic material due to the possibility of emptying it).

Although the multilayer plastic reconstruction of the skull base defect has been designed after intense pursuit for the optimal procedure, it still has a significant drawback: only free flaps are used. Rapid vascularization of plastic material is the essential condition of successful reconstruction of defect; thus, the implanted local tissue has an indisputable advantage in this case. A vascularized pedicle flap demonstrates easier adaptation to the rough defect surface and is more mobile; its use reliably reduces the rate of emergence of postsurgical liquorrhea even in patients subjected to radiation and/or chemotherapy [9]. Such flaps as calvarial periosteum or the temporal muscle require a wide base that would ensure adequate blood supply. Hence, modification of the procedure of closing defects via endoscopic endonasal approach consisted in using local tissues on vascular pedicle.

The musculoperiostal flap can be obtained using nasal septum (the procedure was elaborated by G. Hadad et al. [10]). The pedicle of the flap contains a vascular bundle with the nasoseptal artery, which is a branch of the posterior septal artery (one of the terminal branches of the sphenopalatine artery). Since the flap is harvested...
prior to the main surgical stage, this procedure should be planned beforehand according to a CT scan. The reason behind this is that the endoscopy does not provide a 3D view, thus making it impossible to make correct assessment of the flap size [15]. The musculoperiostal flap can be placed either as the second epidural layer or on top of the adipose graft. Preoperative radiation therapy is the risk factor for necrosis of the flap [8].

The procedure of multilayer plastic reconstruction using adhesive compositions (Tachocomb (Nycomed), Tissucol (Baxter), autologous fat, wide thigh fascia, nasal septal cartilage, and mucoperiostal flap [1] is also employed at the N.N. Burgenko Institute of Neurosurgery when performing endoscopic endonasal removal of skull base tumors, in particular via the extended transphenoidal approaches.

In the reported case, BFP was used for plastic reconstruction of the defect of mesocranial fossa by removing it from the bed via endoscopic endonasal approach without using any additional incisions. The implementation of this procedure requires interconnection between the bed of the resected tumor and the infratemporal fossa. Despite the fact that no intraoperative liquorrhea took place and the dura mater of the mesocranial fossa was intact, there was a defect of the anteroinferior sections of the cavernous sinus, making it necessary to perform plastic reconstruction in order to eliminate its contact with the nonsterile environment of the sinonasal tract.

In normal condition, BFP localizes between the supramaxillary tuber (from the front) and the muscles of mastication (from behind) in the anterior portions of the masticatory space [6, 18]. Despite the fact that the angiofibroma significantly spread to the infratemporal fossa, BFP was displaced only laterally; after the tumor had been resected, BFP became accessible for its relocation to the defect area (Fig. 4).

Conclusion

We consider the proposed technique to be promising and advantageous as part of complex multilayer skull base defect reconstruction after resection of extra- and intracranial mass lesions due to preserved vascular supply of BFP flap in the pterygopalatine fossa (a branch of the supramaxillary artery). If the bone walls of the infratemporal fossa remain intact, the approach to BFP is performed via resection of the posterior wall of the supramaxillary sinus. The method is safe and associated with extremely low risk of complications. We hope that the described flap will be appreciated and will take its place within the range of plastic materials for reconstruction of skull base defects in endoscopic endonasal approach (such as the mucoperiostal flap of the nasal septum and wide thigh fascia).

REFERENCES

The article focuses on a new method for plastic reconstruction of the skull base defect through an endoscopic endonasal approach using a pedicled buccal fat pad flap.

The case demonstrates simplicity and effectiveness of the proposed procedure for closing the defect of the medial sections of the mesocranial fossa formed after the angiofibroma of the skull base had been removed. It has been reported in literature that a fat pad flap is an advantageous method for closing the subdural space and that it should be preferentially used as an internal layer when performing multilayer plastic reconstruction of the skull base defects. Abdominal or thigh fat has been conventionally used for this purpose. The proposed flap is associated with the following advantages: 1) preserved blood supply, which increases its stability and reliability; 2) proximity of the flap harvesting site and the skull base defect; and 3) large flap size, which allows one to efficiently close the long defects. The buccal fat pad apparently better suits plastic reconstruction of lateral defects of the middle sections of the skull base than the medial defects; however, this fact does not belittle its advantage. Extensive clinical experience of open surgeries that has been published by V.A. Cherekaev et al. is indicative of high efficiency and safety of using the buccal fat pad after resection of craniofascial tumors. The endoscopic endonasal approach presumably limits the application of this flap due to the fact that the pterygopalatine and infratemporal fossae need to be dissected in order to harvest it, which does sometimes does not comply with the general approach trajectory. It is predictable that this type of flap will be most frequently used in patients with tumors of the external skull base disseminating in the lateral direction, such as juvenile angiofibroma.

This work is rather topical and significantly contributes to the solution of the problem of reconstructive plastics of cranio basal defects, one of the key problems in endoscopic endonasal surgery of the skull base.

A.Kh. Bekyashev (Moscow)
Glioneuronal Tumor with Neuropil-like Islands in a Neonate


N.N. Burdenko Neurosurgical Institute, Russian Academy of Medical Sciences, Moscow, Russia

Glioneuronal tumor with neuropil-like islands (GTNI) is a rare and relatively “young” histopathological subtype of anaplastic astrocytoma. It consists of diffusely growing astrocytic or oligoastrocytic cells. It was only in the recent WHO classification of tumors (2007) that this tumor was isolated into a new subtype of glial neoplasms [10] and was classified as Grade III malignant tumor.

A total of 43 observations of histologically confirmed GTNI [1–9, 11–17] have been described in English-language literature since 1999, when J. Teo et al. [15] isolated and defined GTNI as an independent subtype of brain neoplasms. Four observations were made in children younger than 18 years of age [5, 12]: the tumor localized in cerebral hemispheres in 3 children (4, 6, and 8-year-old) and in the cervical spine in one child (15 month-old).

We would like to supplement single reports about verification of GTNI in children [5, 12] with an observation of the case with tumor located in the lateral and third ventricles in an infant.

Clinical observation

The inset of the disease in a 11-month-old girl was acute (after a mild cranio-cerebral trauma): the girl fell from her own height and subsequently started to lose acquired skills: became unable to stand and sit; developed flabbiness, adynamia, and regurgitation. MRI of the brain revealed a giant tumor of the lateral and third ventricles and occlusion hydrocephalus (Fig. 1).

A ventriculoperitoneal bypass was mounted to the child at the hospital according to her place of residence; patient’s condition improved to a certain extent: the girl became active and her appetite improved. When admitted to the Burdenko Neurosurgical Institute, the child had clonic spasms of the muscles of the left limbs when head and eyes were rotated to the left. CT scanning of the brain showed the presence of fresh blood in the tumor stroma, which was regarded as tumor hemorrhage (Fig. 2).

After the intensive therapy was performed and patient’s condition has stabilized, total angiography of cerebral vessels was carried out in order to refine the degree of tumor blood supply. No vascular network of tumor was revealed; hydrocephalic dislocation of cerebral vessels was observed (Fig. 3).

Taking into account the presence of the giant brain tumor with fresh hemorrhage in the neonate and the presence of hypertension symptoms despite the bypass that had been mounted previously and the absence of noticeable vascular network of the tumor, a decision was made to perform radical surgery (tumor resection). The surgery was performed on June 18, 2011. The left-sided premotor transcortical—transventricular approach was used. The intraoperative tumor had yellow-pink color and soft consistency; it was mostly removed with a vacuum aspirator (Fig. 4).

As tumor fragments were being removed, the sites with hemorrhage traces were detected. No severe bleeding occurred during the surgery. The intraoperative blood-saving procedures (the use of activated recombinant coagulation factor VII (NovoSeven) — control of coagulation hemostasis and intraoperative reinfusion of autoerythrocytes) that are commonly used in neonates...
during severe blood loss were not employed. The tumor was well-circumscribed from the adjacent tissues, with an exception of a transparent septum infiltrated by the tumor. The child had an episode of hyponatremia in postoperative period, which clinically manifested itself as generalized spasms. Drug correction resulted in normalization of the electrolyte level; no more spasms occurred. The child gradually became more active: she started to produce speech, sit, and play; the wakefulness periods increased.

A morphological examination detected a tumor composed of small cytoplasm-depleted cells with a round-shaped nucleus. In addition, the tumor comprised gemistocytes and well-circumscribed neuropil-like islands containing mature neurons with a large nu-

Fig. 1. MRI scans of an 11-month-old infant with a giant intraventricular tumor.

a – contrast-enhanced T1-weighted MRI, axial cross section; b – contrast-enhanced T1-weighted MRI, frontal cross section.

Fig. 2. Computed tomography scan of the brain in an 11-month infant with a giant intraventricular tumor.

Hemorrhage in tumor stroma.

Fig. 3. Total cerebral angiography of cerebral vessels in an 11-month infant with a giant intraventricular tumor.

No vascular network of the tumor was detected; hydrocephalic dislocation of cerebral vessels (a – right side; b – left side).
Fig. 4. Giant tumor of the lateral ventricle – microscopic view of the surgical wound.

a – appearance of the tumor; b – resection stage: the absence of severe bleeding in the wound can be seen.

Fig. 5. Glioneuronal tumor with neuropil-like islands.

a – general view. ×100; b – neuropil-like island with neurons. ×400 (a, b – hematoxylin and eosin stain); c – immunohistochemical test with synaptophysin. ×200; d – immunohistochemical test with GFAP. ×200; e – immunohistochemical test with the Ki-67 labeling index in the nuclei of dividing cells. ×400.
nucleus and clearly visible nucleoli (Figs. 5, a, b). The tumor had regions with dense arrangement of cells alternating with microcystic glial regions. Rare mitotic figures (2 MFs per 10 high-power fields) were detected; neither necrotic changes nor proliferation of vascular endothelium was observed.

An immunohistochemistry test revealed positive synaptophysin expression in neuropil-like islands (Fig. 5, c) and fibrillary fibers that were spread over the entire tumor and were immunopositive for glial fibrillary acidic protein (GFAP) (Fig. 5, d). The simultaneous expression of synaptophysin and GFAP attests to the bifractional nature of the tumor.

The Ki-67 labeling index was 7% (Fig. 5, e). Thus, the morphological presentation and immunophenotype of the tumor corresponded to GTNI, Grade III according to the 2007 WHO classification.

Contrast-enhanced CT scanning of the brain detected no tumor remnants (Fig. 6). The child was discharged in satisfactory condition on day 14 after surgery. Polychemotherapy (PCT) using the Baby-POG protocol was performed 3 weeks later (the total number of PCT cycles was 3). The control MRI of the brain detected numerous tumor nodes spreading via the ventricular system in the operated area (Fig. 7).

The treatment protocol was changed for the individual treatment regimen using targeted drug Avastin combined with chemo drug irinotecan (CAMPTO). Despite the PCT being carried out, the control MRI of the brain revealed metastases in form of numerous tumor nodes spreading over the entire ventricular system. The clinical and MRI signs of bypass dysfunction were indications for revising and re-mounting the bypass system. After child’s condition stabilized to a certain extent, the PCT course was continued. Regardless of therapy, child’s condition progressively deteriorated and the girl died 9 months after complete resection.

Discussion

One of the first descriptions of GTNI was made in 1999. J. Teo et al. [15] conducted an electron microscope study of tumors in the right hemisphere in 4 adult patients and detected that these tumors contained glial cells and neuropil-like islands that typically contained neurocytic cells and occasionally contained mature emerging neurons. Neuropil is represented by eosinophilic stained acellular foci of tumor tissue. These cells typically (but not always) exhibit a lower proliferation activity as compared to that of the prevailing glial component, which is characterized by a high degree of atypia (Grade III according to the 2007 WHO classification) [10].

It is considered that GTNIs occur more commonly in adult patients and predominantly localize in brain hemispheres [9, 11, 13, 14]. The observations with tumor localization in the spinal cord [6, 7] are less frequent; a single observation of tumor localized in the cervical spine in a 15-month-old child was described [12]. Our observation is the first description of this rare tumor localizing in lateral ventricles that has been diagnosed in a neonate.

The clinical presentations of GTNI typically include epileptic seizures, hypertension signs, mental disorders, or pyramidal signs [1, 7, 15]. In our observation, the disease manifested itself in a neonate after the mild cerebrocranial trauma: hypertension symptoms emerged and the child lost the acquired skills.

The X-ray diagnosis of GTNI has been described insufficiently and is conventionally based on the data obtained by CT and MRI scanning of the brain. According to J. Teo et al. [15] and the CT data, GTNI are represented by well-circumscribed hypodense tumors that usually contain neither petrificates nor cysts. T1-weighted MRI shows a decreased tumor signal intensity as compared to that obtained for the brain cortex. Contrast-enhanced MRI shows that the tumor poorly accumulates the contrast agent. T2-weighted MRI signal from GTNI is hyperintense. In our observation, the tumor signal in a CT scan of the brain was also hypodense, while the T1-weighted MRI signal of the brain is hypodense. When performing contrast-enhanced MRI, the tumor accumulated the contrast agent in the periphery. T2-weighted MRI showed a heterogeneous tumor that had both hypo- and hyperintense inclusions. In our observation, no contrast-accumulating vascular network of the tumor was revealed by angiography (this procedure is equally important in terms of diagnostics and in order a surgeon could determine the risk and volume of possible blood loss).

The differential diagnosis was made by comparing the tumor with neurocytoma, anaplastic astrocytoma, and ependymoma.
Complete surgical resection followed by adjuvant (chemo- and radiation) therapy is a method of choice for treating GTNI [5, 15]. Surgical resection was performed in our case through the left-sided transcortical premotor approach. The tumor had yellow-pink color, was well-circumscribed, and obstructed the foramina of lateral ventricles while spreading to the third ventricle. Despite the large tumor size, the resection procedure was appreciably easy: the tumor was soft, easily removable with a vacuum aspirator; blood loss during the resection was minimal; no clear border between the tumor and the brain tissue could be seen; the wall of the lateral ventricle was the site of initial growth.

According to different authors [5, 15], the 3-year survival rate varies from 50 to 75%. It is a commonly known fact that radiation therapy is not performed in neonates. A small series of observations of radiating patients with glioneuronal brain tumors with neuropil-like islands was made for older children [5]. In our case, regardless of the fact that adjuvant PCT was performed after the complete resection of the tumor, progression of tumor growth was observed 2 months after surgery. Isolated cases of leptomeningeal metastases have been described in literature [7, 12, 14]. No radiation therapy was performed because of the patient’s age; as a result, the child died 7 months later. This observation is indicative of the fact that new regimens of combined therapy

---

Fig. 7. MRI of the brain.
I – after the first course of PCT (2 months after complete removal of the tumor); numerous tumor nodes metastasizing via the ventricular system;
II – after the second course of PCT (9 months after complete removal of the tumor); metastatic process (in the form of tumor nodes metastasizing via the entire ventricular system).
Contrast-enhanced T1-weighted MRI: a – axial cross section; b – sagittal cross section.
for this type of tumors need to be searched for (including high-dose PCT with stem cell support).

Conclusion

The case of GTNI localizing in the lateral ventricle in a neonate, which manifested itself at the age of 11 months in form of hypertension, was first reported. The potential for complete removal of these tumors despite their large size and young age of the child is presented. However, regardless of the completeness of removal and polychemotherapy, the prognosis in infants with GTNI can be extremely unfavorable; progression in the form of tumor implantation into ventricular ependyma may occur in case of intraventricular localization of the tumor.

Acknowledgments

The authors are grateful to Prof. A.G. Korshunov for his participation in making the histological diagnosis.

REFERENCES


Commentary

A thorough description of the case from clinical practice of S.K. Gorelyshev et al. is of interest due to the fact that glioneuronal tumor with neuropil-like islands is a very rare brain neoplasm. Moreover, the definition “glioneuronal tumor with neuropil-like islands” has started to be used by neuropathologists, neurosurgeons, and neurooncologists not long ago. The term “glioneuronal” in the tumor name means that it should be placed in the registry of tumors of the central nervous system in the section “Neuronal and mixed glioneuronal tumours”. However, the existing WHO classification places it in the chapter “Anaplastic astrocytoma” within the section “Astrocytic tumors”, which can be associated with the fact that the glial component predominates in this tumor and it is characterized by diffuse-type growth.

It should be mentioned that this tumor has been included in the setting of neuropil-like islands in a number of guidelines (e.g., AFIP Atlas of Tumor Pathology, 2007).

A glioneuronal tumor with neuropil-like islands (malignancy Grade 3 according to the WHO classification) was diagnosed in the reported case; thus, it can be formally classified as a malignant neoplasm based on this fact alone. In addition to histological malignancy, the unfavorable factors include the giant size of the tumor and localization in the lateral and third ventricles, which has presumably caused the very early and multifocal metastases via the ventricular system.

As mentioned by the authors, a total of 43 observations of the tumor of this nosology have been described in English-language literature (and only 4 cases in children). The unique nature of this report is that the tumor in this case localized in the ventricular system of the brain and the transparent septum, which is more typical of neurocytomas. The value of this article is also associated with the fact that it will contribute to the total set of the described observations of glioneuronal tumor with neuropil-like islands (provided that it is published in an English-language journal). In turn, this will contribute to integrating the data on its genetics, epidemiology, pathohistology, prognosis, methods for surgical treatment, and chemotherapy protocols.

A.N. Kislyakov (Moscow)
Working Results of the Electronic On-line Version of the Spine Registry for Degenerative Lumbar Spine Diseases and Study of Its Synchronization Capacity with the Electronic Case History


N.N. Burdenko Neurosurgical Institute, Russian Academy of Medical Sciences, Moscow, Russia; Neurosurgery Department of the Nizhny Novgorod Research Institute of Traumatology and Orthopedics

Objective: To assess the results of using the lumbar spine on-line registry in the IV quarter of 2012.

Materials and Methods: The researchers of the Burdenko Neurosurgical Institute of the Russian Academy of Medical Sciences (RAMS) and the System Analysis Institute of the Russian Academy of Sciences (RAS) have developed an electronic on-line portal of the Spine Registry for Degenerative Lumbar Spine Diseases. The data on 1295 retrospective and 145 prospective patients who underwent treatment at the Burdenko Neurosurgical Institute, at AXIS clinic, at the Medical Center of the Bank of Russia, at Marina Spine Clinic (LA, USA), and at the Neurosurgery Department of the Research Institute of Traumatology and Orthopedics (Nizhny Novgorod, Russia) were analyzed.

Results and Discussion. Since May 2012 to the present time, the outcomes of 1295 (retrospective group) and 145 (prospective group) patients with degenerative lumbar spine diseases who had undergone treatment in the period between 2002 and 2012 were entered into the online registry and subsequently analyzed. The current study has revealed two problems that need to be discussed. The first problem is that the archived information is not sufficient for database update. The second problem is associated with low activity of many physicians in inputting data into the register. We believe that the solution to these problems lies in the field of synchronizing the on-line registry with electronic medical records. This synchronization between the registry and the online records will allow one to study their joint activity. If the results obtained after the other sections of the register had been developed turn out to be positive, they will be added to the already running version as provided by the principles of its performance (scalability and extensibility).

The result of this work will be the profile of vertebrological version of electronic medical records. In future it could be used in clinics dealing with spine disorders. The perspective of this work is to develop other parts of spine registry (for cervical and thoracic spine) and to improve the outcome assessment process in Russian spinal surgery clinics.

Keywords: outcome, spine register, case report, synchronization, degenerative diseases of the spinal column, prognosis, treatment goals, evidence-based medicine.

Surgical treatment of degenerative disorders of the lumbosacral spine is a dynamically developing area in vertebrology. According to the reports of foreign researchers, the annual number of surgical interventions for these diseases has noticeably increased over the past decade. In particular, more than 200,000 surgeries of this kind are annually performed in the United States [1, 2, 5, 13, 14]. What is this dynamics based on? There are several reasons behind this fact. According to the WHO data, the average life expectancy in developed countries is known to increase, while the degenerative diseases accompany aging. This fact is associated with the epidemiological aspect; in this connection, the increase in the number of surgical interventions is partially the forced necessity. Another equally important factor is the wide dissemination of modern diagnostic methods (in particular, MRI), which improves the detectability of these diseases, thus increasing the number of potential candidates for surgical therapy. One should also bear in mind that these surgeries are sophisticated and technologically intensive. A lot of them imply that various grafts are used intraoperatively [8, 11]. A significant variety of surgical methods underlies the necessity for decision making regarding which variant is the optimal one in each particular case. It is not a secret that there is a commercial component in using grafts, which is currently being widely discussed at foreign conferences. The situation when different protocols of surgical intervention are offered to the same patient with a degenerative pathology of the lumbosacral spine by different physicians is quite typical today. In these cases, the patient is forced to consult several experts to choose the adequate treatment method, which takes quite a long time.
Decision making regarding the method of surgical treatment is based on several key factors, including safety and efficiency of the treatment method, prognosis of the treatment outcome, potentiality of achieving (totally or partially) the desired goals [6, 10].

Randomized controlled trials are known to be the gold standard for assessing the efficiency of a certain method. The ponderability of observational studies (such as prospective and retrospective observation of patient groups or the case—control studies) is either low or absent at all. However, in some cases it is either impossible to conduct a randomized controlled study or this study is limited (because of a long-term outcome when placing a graft or insufficient number of participants). Specialized registries with data being input prospectively are typically used in these cases [7, 9]. Experience of individual physicians and clinics is insufficient to collect the data regarding the efficiency of the rapidly advancing set of surgical techniques. It is clear today that the tasks that have been formulated are to be solved using information technologies. The focused effort of individual researchers and teams of physicians in the integrated information space for solving a set of tasks aimed at increasing physician’s certainty when making a decision regarding the optimal surgical treatment method is a topical problem of vertebrology. In our case, it is a system for supporting decision making regarding the optimal surgical treatment method for a patient with degenerative disorder of the lumbosacral spine [3, 4]. Interactive information services showing the traffic jams are a simple example of the system component ensuring the support for decision making, which is of special importance for the residents of large cities. It is quite a usual routine for a driver to consult these data portals (e.g., Yandex Traffic Jams) when planning one’s route. In other words, it is an example of using auxiliary technologies to increase one’s certainty about the adequacy of choice when making a decision. We consider that designing these technologies is quite topical for clinical medicine.

The present study is aimed at analyzing the results of using the lumbar spine on-line registry (the joint work of the specialists of the Department of Spinal Neurosurgery of the Burdenko Neurosurgical Institute of the RAMS, the Medical Center of the Bank of Russia, and the Neurosurgery Department of the Nizhny Novgorod Research Institute of Traumatology and Orthopedics in the IV quarter of 2012.

Materials and Methods

The researchers of the Burdenko Neurosurgical Institute and the System Analysis Institute of the RAS have developed and launched the electronic on-line portal of the Spine Registry for Degenerative Lumbar Spine Diseases (www.spineregistry.ru, Fig. 1).

The main functions of the registry include collection, processing, and storage of the demographic data about the patients and the data obtained during treatment; formation of disease profiles, analysis of the treatment outcomes, construction of prognostic models, searching for evidence, and development of the layout of statistical data collection (in this case, in vertebrology). It is noteworthy that along with the evident advantages, the registry has latent benefits as well. In particular, the registry will allow one to keep track of migration of patients who may refer to a different physician if dissatisfied with the proposed treatment. Both in this case and in case of analyzing the results of work of a certain physician, the

![Fig. 1. Webpage of the spine registry.](image-url)
registry should not be regarded as a tool for detecting physicians who provide insufficiently efficient therapy. Instead, it should be regarded as a tool for increasing the number of physicians who provide efficient therapy. It should be mentioned that the designed software complex is not simply a knowledge base about the patients enabling one to conduct a statistical analysis. It is the technology for supporting decision making regarding the optimal treatment method for a patient with degenerative pathology of the lumbosacral spine. This technology allows one to choose the surgery method with allowance for the data about its efficiency, the outcome prognosis, and individual objectives of the patient. The technology designed is shown in scheme (Fig. 2).

When developing the portal on-line registry, we have studied the experience of the foreign colleagues who have made significant progress in this area. Spine Tango is the most successful foreign registry that has been functioning in the EU countries since the late 1990s (Fig. 3). A comparative analysis of the proposed registry and Spine Tango is presented in Table 1.

Functioning of the registry is based on the fact that a completed clinical case (i.e., all the data regarding a patient who received surgical treatment for a degenerative disease of the lumbosacral spine) is the core of the registry. Hence, it is extremely important to initially assess to what extent the medical records of the patients filled out every day are useful for us. As already mentioned, the requirements to criteria have been initially formulated, including the following ones: significant characteristics of a patient and disease; thorough record of the therapy and diagnosis process; comprehensive characterization of treatment outcome. The justification of the inclusion of these criteria needs to be objectively proved, while the combination of these criteria needs to allow one to compare them to the data of foreign registries in order to integrate the results in the global system of studying spine pathologies.

With allowance for the requirements listed above, a total of 83 criteria have been included in the registry. In our opinion, these criteria shape a comprehensive virtual image of a patient who received surgical treatment for degenerative disease of the lumbosacral spine. All the criteria have been publicly discussed at the conferences (Novosibirsk, June 2012; Moscow, May 2011) and on on-line platforms of the electronic portals “vertebrolo-

![Fig. 2. Procedure for supporting the decision making process.](image-url)
Since May 2012 to the present time, the data from the electronic medical records of patients who had undergone surgical treatment for degenerative lumbosacral spine diseases in 2002–2012 at the Burdenko Neurosurgical Institute, at the Medical Center of the Bank of Russia (a retrospective group of patients), and at Axis clinics have been input into the registry. The prospective data were entered simultaneously. This study presents the results of using the on-line registry in the IV quarter of 2012 (September through December 2012). All the patients

Table 1. Comparative analysis of the Russian registry and the Spine Tango registry

<table>
<thead>
<tr>
<th>Criterion for comparison</th>
<th>Spine Tango spine registry</th>
<th>Russian Spine Registry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Online access</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Multi-linguisticity</td>
<td>+ (including the Russian language since 2012)</td>
<td>—</td>
</tr>
<tr>
<td>Duration of inputting data (time required to input the data about one patient)</td>
<td>15 min</td>
<td>25 min</td>
</tr>
<tr>
<td>Opportunity for inputting data on all spine sections</td>
<td>+</td>
<td>In future, yes. Only the lumbosacral spine at the present time</td>
</tr>
<tr>
<td>Opportunity for inputting data on conservative treatment</td>
<td>+</td>
<td>—</td>
</tr>
<tr>
<td>Opportunity for inputting data on patient’s neurological status</td>
<td>—</td>
<td>+</td>
</tr>
<tr>
<td>Opportunity for inputting data obtained via neuroimaging methods</td>
<td>—</td>
<td>+</td>
</tr>
<tr>
<td>Existence of an integrated classification scheme for treatment outcomes</td>
<td>—</td>
<td>+</td>
</tr>
<tr>
<td>Opportunity for taking into account the patient-centered treatment objectives</td>
<td>—</td>
<td>+</td>
</tr>
<tr>
<td>Making allowance both for specialization and competence of an attending doctor</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Making allowance for surgical characteristics (duration, blood loss volume, etc.)</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Opportunity for forming statistical reports</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Prognosis of outcomes</td>
<td>—</td>
<td>+</td>
</tr>
<tr>
<td>Number of criteria taken into account</td>
<td>52</td>
<td>83</td>
</tr>
</tbody>
</table>

Fig. 3. Webpage of the Spine Tango registry.
had undergone different variants of surgical treatment at the Burdenko Neurosurgical Institute, at the Medical Center of the Bank of Russia, and the Neurosurgery Department of the Nizhny Novgorod Institute of Traumatology and Orthopedics. Table 2 lists the data regarding the quantitative structure of the patients who had received therapy at different clinics.

The distribution of patients over nosological forms is shown in Table 3.

The experience of entering the data about the patients in the registry and analyzing the resulting data allowed one to reveal two problems.

The first problem is that the information contained in the medical history usually appears to be insufficient when being entered into the registry. We analyzed the electronic medical records of patients at the Burdenko Neurosurgical Institute to single out the sections lacking the data. The commentaries to the sections of the medical history being filled out are listed in Table 4. The second problem is associated with low activity of many physicians in inputting data into the register (the data on a significant number of patients have not been input at all). We believe that these problems are interconnected to some extent and their solution requires a systematic approach to be used.

**Discussion**

An analysis of the situation demonstrates that the problems associated with insufficient data in medical history of the patients with degenerative diseases of the lumbar-sacral spine and slow updating of the registry can be solved simultaneously.

As it has been mentioned earlier, the main constraint of updating the registry is that the physicians show little activity in inputting the data, since entering the data requires precious working time. However, there are grounds for believing that we still will need to solve this difficult issue. It can be expected even today that as we follow in the footsteps of the other countries, we will encounter the increasing impact of the insurance companies that require accurate argumentation why a particular treatment method had been selected very soon. In this case, the registry, which is the source of data required for decision making, can be an “information shield” for us. It is common knowledge that additional duties without compensation always cause negative attitude of the employees; the situation with the registry is not an exception. However, the computerization experience is indicative of rapid adaptation to the software provided that there is actual benefit associated with using it, simple work, and convenient interface. Hence, we try to focus the main effort on ensuring compliance of the registry to all these requirements.

The existing experience gives grounds for believing that the solution to these problems lies in the field of synchronizing the on-line registry with electronic medical records. It should be mentioned that the absence of the electronic medical records at many clinics is not
a problem in this case. On the contrary, now we have an opportunity to design the optimal version of “vertebrological medical records” and subsequently implement it into practice at clinics dealing with treatment of spine diseases. We can start synchronizing the electronic medical records with the already functioning spine registry right now. As soon as the other sections are developed they will be added to the already running version. This potentiality is provided by the principles of performance of the registry (scalability and extensibility).

Let us return to the name of our article and invite all the experts to participate in discussion and development of the registry. We will be glad to any cooperation.

**Conclusion**

1. Spine registry allows one to accelerate the accumulation of the data on patients who had undergone surgical treatment for degenerative disease of the lumbosacral spine.

2. Spine registry provides an integrated platform for physicians from different clinics and different Russian cities.

3. Experts from different clinics should take part in the development of the spine registry by making proposals for its optimization.

4. Synchronization of the registry with the electronic medical records is a significant stage of its development.

5. The question regarding the development of unified vertebrological electronic medical records synchronized with the spine registry is an important disputable aspect.

**REFERENCES**


**Table 4. Commentaries to the sections of the electronic medical record**

<table>
<thead>
<tr>
<th>Section of the medical record</th>
<th>Commentaries to the section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal details (front page)</td>
<td>A lot of medical records contained no e-mails, data on patient’s education or occupation. Assessment of the treatment outcomes requires dynamic consultation of patients, specification of the date and requirements (requirements to the studies, evaluation scales, etc.) that can be automatically e-mailed to the patients or their relatives provided that the e-mail address was provided.</td>
</tr>
<tr>
<td>Primary inspection</td>
<td>Lack of data regarding patient’s height, personal habits (smoking), duration of disease presentation and the acute condition. When describing the associated pathology, attention is usually paid to anesthesiologically important diseases only.</td>
</tr>
<tr>
<td>Neurological examination</td>
<td>According to our observations, it is the section of medical history that is filled out most thoroughly.</td>
</tr>
<tr>
<td>Clinical summary</td>
<td>No treatment objectives (neither patient-centered nor surgical ones) are usually formulated in this section. The description of X-ray signs is typically the same as that in the diagnosis section.</td>
</tr>
<tr>
<td>Diagnosis</td>
<td>The diagnosis is frequently formulated in the arbitrary form; it is almost impossible to search for patients based on the diagnosis, which suggests that this important section of the electronic medical record needs to be structurized.</td>
</tr>
<tr>
<td>Therapy course and surgical protocol</td>
<td>The shortcoming of this section is that the surgical protocol has an arbitrary form. Such data as surgery duration, blood loss volume are not provided; the type of decompression performed is not unified; intraoperative complications are specified very rarely. When repeating the surgeries, the protocols of the earlier intervention usually turn out to be poorly informative.</td>
</tr>
<tr>
<td>Outcomes</td>
<td>The treatment outcome is evaluated by a physician only and only in the generalized form (improvement, no improvement, condition at the preoperative level).</td>
</tr>
</tbody>
</table>

**N.N. BURDENKO JOURNAL OF NEUROSURGERY 2, 2013**
Commentary

This article written by a group of researchers is devoted to studying the experience of implementing the spine registry (an on-line version developed to study the outcomes of surgical treatment for degenerative disorders of the lumbosacral spine) into practice.

The urgency of this article is associated with the high incidence rate of degenerative spinal disorders and with the lack of consistency between the long-term outcomes of surgical treatment in some cases. A significant number of new methods for surgical management of degenerative spinal disorders have been developed over the past decade. The area of surgical management of these diseases has progressed from decompression surgeries to the surgeries aimed at recovering the lost functions of vertebral segments. Thus, we currently have a vast set of techniques for treating the degenerative disorder of the lumbosacral spine. As the authors have noted, we frequently face situations when different surgical treatment procedures are offered by different physicians to manage the same patient. This very situation illustrates the complicated problem of selecting the optimal treatment technique for a particular patient. It is noteworthy that both the physician and the patient face this problem. Efficiency assessment is one of the main and significant factors characterizing any treatment procedure. In an ideal situation, a randomized controlled trial is the standard.

The authors report the problems they faced when implementing the registry. It should be mentioned that adaptation of physicians and their desire to enter their data into the registry will hardly be a quick process. This fact is illustrated by the experience of using registries in other countries. Nevertheless, the significance of work performed is beyond any doubt. In my opinion, further development of the registry should rely on the pursuit for making the user–registry interaction simpler and quicker. In this connection, the idea of synchronizing the registry with the process of entering the medical records can be rather promising; hence, this question needs to be further elaborated together with IT experts.

However, having read the article I came up with a number of questions:

1. How many physicians have registered at the website?
2. How many experts have responded to the invitation to the discussion and what proposals have been made?
3. How often do the physicians send tasks for prognosing the outcome?
4. Are there any plans to establish the Registry Committee within the Russian Association of Spinal Surgeons (RASS)?

In conclusion, I would like to emphasize that the article undoubtedly deserves being published; the further development of the registry should be regarded as a general task for the members of the Russian Association of Spinal Surgeons.

S.T. Vetrile (Moscow)
Microsurgical Selective Neurotomy in Treatment of the Focal Spastic Syndromes of Different Etiology

A.V. DEKOPOV, V.A. SHABALOV, A.A. TOMSKY, M.A. KHIT, E.M. SALOVA

N.N. Burdenko Neurosurgical Institute, Russian Academy of Medical Sciences, Moscow, Russia

Objective. To estimate the effectiveness of selective peripheral neurotomy (SPN) in treatment of local botulinum toxin resistant spastic disorders.

Methods. 20 SPNs were performed in 18 patients with spastic disorders. In 11 cases we performed SPN of the nervus obturatorius, in 5 – nervus tibialis, in 3 – musculocutaneous nerve, and in 1 – nervus radialis. The results of surgical treatment were estimated by the Ashworth Scale and the Gross Motor Function Measure (GMFM-88). These data were statistically processed.

Results. A significant decrease in spasticity was observed in most cases: from 4.02±0.52 points before surgery to 1.86±0.63 points after surgery (p<0.001). A significant improvement in motor functions from 50.7±12.92% before surgery to 54.9±13.6% after surgery (p<0.001) was observed in 11 cases.

Conclusion. SPN is an efficient procedure that significantly reduces spasticity, improves the range of active and passive movements in patients with spastic disorders and the motor function.

Keywords: spasticity, neurotomy, infantile cerebral palsy.

Spastic disorders accompany a number of neurological pathologies. These pathologies include consequences of spinal cord injuries, acute disturbance of cerebral and spinal cord blood flow, infantile cerebral palsy, multiple sclerosis, and other neurodegenerative disorders. Muscle hypertonicity limits the range of active and passive movements and the rehabilitation potential, and can also result in the development of fixed contractures and deformities of the locomotor system if the disease coexists for a long period of time. In many cases, spasticity causes the development of pain syndrome.

Management of spastic syndromes includes conservative therapy, physiotherapy, orthosis, therapy using botulinum toxin, and neurosurgical interventions. Conservative and physiotherapeutic treatment is typically efficient in patients with mild and moderate spastic syndromes. If the muscle tone significantly increases (Ashworth score of 3 and higher), the more radical treatment procedures need to be used. In patients with generalized forms of spastic syndrome involving a large number of muscle groups, neurosurgical intervention is the optimal management method. Surgical procedures include posterior selective rhizotomy, DREZ-tomy (destruction of the dorsal root entry zone), chronic electrostimulation of the spinal cord, and chronic intrathecal therapy using implantable pumps [1, 2, 6, 14]. Botulinum toxin therapy is frequently used in patients with local spastic syndromes [3]. However, if this type of therapy has either little or no effect, selective neurotomy needs to be performed.

Selective neurotomy is based on partial resection of motor peripheral nerve fascicles. This surgery was first performed by F. Lorenz in a patient with lower spastic paraparesis in 1887 [8]. In 1912, A. Stoffel was first to perform neurotomy of the median nerve by intercrossing motor fascicles inside the nerve trunk [14]. This surgery was not widely applied during this time because of a large number of complications associated with it: muscle weakness, sensory processing disorders, and pain syndrome. However, in 1976, Gross (quoted in [9]) introduced selective neurotomy to the general clinical practice due to the use of microsurgical equipment and neurophysiological mapping. Selective neurotomy is now widely used to treat botulinum toxin-resistant upper and lower limb spasticity.

Material and Methods

A total of 18 patients [(15 (83%) males and 3 (17%) females, aged 3–43 (mean age 10.8 years)] were included in the study (see Table). Spasticity resulted from infantile cerebral palsy (ICP) in 14 (77%) patients; cranioencephal injury in 1 (6%) patient; and spinal maldevelopment in 1 (6%) patient. Lower and upper spastic paraparesis was observed in 14 (77%) and 4 (23%) patients, respectively. Crossed leg palsy associated with spasticity in the adductor muscles of the hip was observed in 11 patients; 5 patients had equinus foot deformity associated with spasticity in the triceps muscle of calf. In 3 cases, predominant spasticity was observed
## Outcomes of surgical treatment

<table>
<thead>
<tr>
<th>Observation №</th>
<th>Patient’s age and diagnosis</th>
<th>Neuroromy – nerve</th>
<th>GMFM, % before surgery</th>
<th>Tone, points before surgery</th>
<th>GMFM, % after surgery</th>
<th>Tone, points after surgery</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7 years, ICP</td>
<td>Musculocutaneous nerve</td>
<td>10</td>
<td>4.5</td>
<td>2</td>
<td>Satisfactory</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>5 years, ICP</td>
<td>Nervus obturatorius</td>
<td>35</td>
<td>4</td>
<td>1.5</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>23 years, spinal injury</td>
<td>«</td>
<td>45</td>
<td>55</td>
<td>3.5</td>
<td>1.5</td>
<td>«</td>
</tr>
<tr>
<td>4</td>
<td>3 years, ICP</td>
<td>«</td>
<td>37</td>
<td>40</td>
<td>4</td>
<td>1.5</td>
<td>«</td>
</tr>
<tr>
<td>5</td>
<td>6 years, ICP</td>
<td>«</td>
<td>43</td>
<td>46</td>
<td>4</td>
<td>1</td>
<td>«</td>
</tr>
<tr>
<td>6</td>
<td>3 years, ICP</td>
<td>«</td>
<td>62</td>
<td>65</td>
<td>4</td>
<td>1.5</td>
<td>«</td>
</tr>
<tr>
<td>7</td>
<td>6 years, ICP</td>
<td>«</td>
<td>45</td>
<td>45</td>
<td>4</td>
<td>«</td>
<td>Unsatisfactory</td>
</tr>
<tr>
<td>8</td>
<td>3 years, ICP</td>
<td>Musculocutaneous nerve</td>
<td>23</td>
<td>23</td>
<td>5</td>
<td>2</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>9</td>
<td>7 years, ICP</td>
<td>Nervus tibialis</td>
<td>65</td>
<td>68</td>
<td>3</td>
<td>1</td>
<td>Good</td>
</tr>
<tr>
<td>10</td>
<td>7 years, ICP</td>
<td>Nervus obturatorius</td>
<td>51</td>
<td>55</td>
<td>4</td>
<td>2</td>
<td>«</td>
</tr>
<tr>
<td>11</td>
<td>4 years, ICP</td>
<td>Nervus tibialis + nervus obturatorius</td>
<td>32</td>
<td>34</td>
<td>4,5</td>
<td>2</td>
<td>«</td>
</tr>
<tr>
<td>12</td>
<td>3 years, ICP</td>
<td>Nervus tibialis</td>
<td>65</td>
<td>71</td>
<td>4</td>
<td>1.5</td>
<td>«</td>
</tr>
<tr>
<td>13</td>
<td>31 years, ICP</td>
<td>Nervus obturatorius</td>
<td>37</td>
<td>37</td>
<td>4</td>
<td>2</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>14</td>
<td>8 years, spine maldevelopment</td>
<td>«</td>
<td>40</td>
<td>40</td>
<td>4</td>
<td>2</td>
<td>«</td>
</tr>
<tr>
<td>15</td>
<td>5 years, ICP</td>
<td>Nervus tibialis + nervus obturatorius</td>
<td>58</td>
<td>60</td>
<td>4</td>
<td>2</td>
<td>Good</td>
</tr>
<tr>
<td>16</td>
<td>42 years, spinal injury</td>
<td>Nervus radialis</td>
<td>65</td>
<td>72</td>
<td>5</td>
<td>2</td>
<td>«</td>
</tr>
<tr>
<td>17</td>
<td>6 years, ICP</td>
<td>Nervus tibialis</td>
<td>40</td>
<td>40</td>
<td>3</td>
<td>2</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>18</td>
<td>27 years, craniocerebral injury</td>
<td>Musculocutaneous nerve</td>
<td>35</td>
<td>35</td>
<td>4</td>
<td>2</td>
<td>«</td>
</tr>
</tbody>
</table>
in the biceps and triceps muscles of arm, resulting in elbow flexion deformity.

All the patients received conservative drug therapy using central muscle relaxants (Bacoﬂen, Sirdalud) prior to the surgery. Drug therapy showed no effect in all cases. All the patients were subjected to 2–4 courses of botulinum toxin therapy using Dysport prior to the surgery. The therapy had no effect in 12 cases. In 6 patients, a good clinical effect was observed in the beginning of the therapy, while the subsequent injections showed no effect. Seven patients received preliminary neurosurgical treatment: posterior selective rhizotomy at the lumbar level in 3 patients; implantation of chronic electrodes on the lumbar thickening of the spinal cord and implantation of an Itrel3 neurostimulation system in 4 patients. The effect of neurosurgical therapy was incomplete; spasticity in individual muscle groups was retained.

All the patients were included in the study (2010–2012). The catamnestic follow-up varied from 1.5 to 2 years. The inclusion criteria were as follows: high spasticity level (score of 3 and higher); resistance to conservative drug and physiotherapy; resistance to botulinum toxin therapy.

The exclusion criteria were as follows: severe deformities of the locomotor apparatus; general contraindications for surgical treatment and general anesthesia.

Prior to the surgery, all patients underwent a thorough examination by a neurosurgeon, a neurologist, a physiatrist, and an orthopedist. The muscular tone was assessed for each muscle group using the Ashworth scale (score of 1–5). The range of passive and active movements was also assessed by recording the video of the standard motor testing and walking. The locomotor status was evaluated using the standardized GMFM-88 scale. The same examination was carried out 3, 6, 12, and 24 months after surgery. The pre- and postoperative indicators of muscle tone and the locomotor status were statistically processed using the Wilcoxon test. The value \( p<0.05 \) was considered to be statistically significant.

Twenty neurotomies were performed in 18 patients: neurotomy of nervus obturatorius in 11 cases; of nervus tibialis in 5 cases; of musculocutaneous nerve in 3 cases; and of nervus radialis. General anesthesia via i.v. infusion of propofol was used in all patients. Only short-acting myorelaxants were used for intubation in order to avoid suppressing the motor responses during intraoperative electromyography. Patient’s position on the operating table depended on the type of neurotomy. When performing neurotomy of nervus tibialis, the patient was placed facedown. When performing neurotomy of musculocutaneous nerve, the patient was placed on his back with legs outstretched. When performing neurotomy of musculocutaneous nerve, the patient was placed on his back with an arm outstretched to 90 degrees. Intraoperative electromyography was recorded on an 8-channel myograph system VIKING select (Nicolet, USA). Needle electrodes were placed in the muscles selected for the study. The electrodes were placed in m. adductor longus and brevis et magnus when performing neurotomy of nervus obturatorius; in m. soleus and m. gastrocnemius in case of neurotomy of nervus tibialis; in m. biceps brahii and m. extensor carpal radialis in case of neurotomy of nervus radialis. Intraoperative electrostimulation was conducted in the bipolar mode at a stimulus frequency of 4–7 Hz and amplitude of 0.5–10 mA.

**Neurotomy of musculocutaneous nerve.** Longitudinal skin incision was made along the medial bicipital groove from the margin of the greater pectoral muscle 4–5 cm downward. After opening the fascia, the intermuscular space between the biceps in the lateral direction and the brachial muscle in the medial direction was prepared. After the trunk of the musculocutaneous nerve had been detected, a surgical microscope was mounted. Epineurium was opened up within 8–10 mm; the nerve was divided into fascicles. Next, intraoperative electrostimulation was performed. The motor and sensory fascicles were differentiated. The motor fascicles providing high-amplitude motor responses were coagulated within 8–9 mm and excised. A total of 50–65% of all fascicles comprising the motor portion of the nerve were cut depending on the results of stimulation electromyography.

**Neurotomy of nervus radialis.** Skin incision was made along the deltoid groove 2 cm below collar bone until the linea axillaris anterior. The greater and the lesser pectoral muscles were sutured and cut. Secondary trunks of the brachial plexus were prepared in fatty tissue. After imaging of the posterior secondary trunk, the site where the circumﬂex nerve comes oﬀ was determined and the trunk of nervus radialis was isolated. The epineurium was opened up along 8–10 mm; next, nervus radialis was divided into fascicles. The fascicles involved in innervations of the triceps muscle of arm were verified by intraoperative electrostimulation. The motor fascicles providing high-amplitude motor responses were coagulated within 8–9 mm and excised.

**Neurotomy of nervus tibialis.** A 5 cm long Z-shaped skin incision was made through the midline of the popliteal space. After the fascia in the subcutaneous adipose tissue of the popliteal space was opened up, the neurovascular bundle comprising the popliteal artery, the popliteal vein, and the trunk of nervus tibialis was prepared. Muscular branches were prepared and isolated after imaging the nerve trunk. Branches leading to the lateral and medial head of the gastrocnemius muscle and the branch leading to the soleus muscle were isolated in patients with equinus foot deformity. In patients with talipes equinovarus and internal foot rotation, the branch leading to the posterior tibialis muscle was also isolated. Next, epineurium on the muscular branches was opened up within 9–10 mm, and the muscles were divided into 3–4 fascicles. Coagulation and excision was performed in 50–65% of fascicles comprising the muscular branch under the control of intraoperative electromyography.
Neurotomy of nervus obturatorius. Skin incision was made along the internal surface of the hip starting from the inguinal fold (4–5 cm downward). After the fascia had been opened up, the intermuscular space between m. adductor longus and m. gracilis was prepared. Next, the anterior branch of nervus obturatorius on m. adductor brevis was imaged. The nerve had a loose structure in about half of all cases. After the nerve had been divided into fascicles, coagulation and excision was performed in 50–75% of fascicles comprising the muscular branch under the control of intraoperative electromyography (Fig. 1).

The patients stayed at hospital for 7 days after surgery until suture removal. Active rehabilitation procedures were started immediately after discharge.

Results

A significant reduction in degree of spasticity (Ashworth score from 4.02±0.52 before surgery to 1.86±0.63 after surgery) was observed in most patients \((p<0.001)\). No significant reduction of spasticity occurred in 1 case only (observation № 7, see Table).

Among three patients subjected to neurotomy of the musculocutaneous nerve, complete the restoration of the range of movement in the elbow joint was observed in two patients (Fig. 2). In one case, the range of movement was restored only to 50%, which was associated with the fixed contractures. Orthopedic surgery was recommended.

Among 11 patients who were subjected to neurotomy of nervus obturatorius, total regression of crossing of the legs was observed in 6 (54%) patients (Fig. 3). In the remaining 5 patients, crossing of the legs was partially retained despite the regression of the spastic syndrome in the adductor muscles. All these patients had severe hip joint subluxation. Wearing of the swash plate type apparatus was recommended to these patients.

Among 5 patients who underwent neurotomy of nervus tibialis, complete regression of equinus foot deformity was attained in 4 (75%) individuals (Fig. 4). Partial effect was observed in one patient with talipes equinovarus despite the regression of spastic syndrome in the gastrocnemius and posterior tibialis muscles. Orthopedic surgery was recommended to this patient.

The patient who had undergone neurotomy of nervus radialis for spasticity in the triceps muscle of arm showed complete restoration of the range of movement in the elbow joint.

No postoperative complications were observed in this series of cases. Recurrent spastic syndrome was observed during the catamnestic follow-up in none of the patients. The dynamics of the locomotor function was

*Fig. 1. Stages of selective neurotomy.*

\(a\) – isolation of motor fascicles; \(b\) – intraoperative electrostimulation; \(c\) – separation into fascicles; \(d\) – coagulation of fascicles.
Fig. 2. Outcome of selective neurotomy of the musculocutaneous nerve.

a – before surgery; b – 1 week after surgery. An increase in the range of movements in the elbow joint is observed.

Fig. 3. Outcome of selective neurotomy of nervus obturatorius.

a – before surgery; b – 1 week after surgery. Regression of leg crossing is observed.

Fig. 4. Outcome of selective neurotomy of nervus tibialis.

a – before surgery; b – 1 week after surgery. Regression of equinus foot deformity is observed.
Discussion

The use of microsurgical equipment and intrathecal baclofen infusion for spasticity in cerebral palsy is aimed at recovering the lost balance between the agonist and antagonist muscles. Hence, in each specific case a question arises what percentage of fascicles should be resected. Excessive resection of nerve fibers causes the development of muscle weakness and a negative functional outcome. Insufficient resection results in spastic syndrome recurrence. Intrathecal baclofen infusion for spasticity of cerebral origin causes a diffuse reduction of muscle tone, which may impair the execution of associated movements in patients with local spastic syndrome [1, 4, 5]. Hence, the ITB procedure is optimal to treat patients with diffuse spasticity. Selective neurotomy is more efficient in patients with local spasticity. Furthermore, this procedure can be used to supplement ITB when the effect on spasticity in the upper limbs is insufficient. DREZ-tomy is the most efficient procedure to manage the spastic syndrome [10]. However, DREZ surgery can be performed only if the other neurosurgical techniques prove to be inefficient, since it has a large number of potential complications [6].

Conclusions

Selective neurotomy can be used in patients with local spasticity when the conservative and botulinum toxin therapies prove to be inefficient. Surgical treatment causes a significant regression of the spastic syndrome, increases the range of active and passive movements, and improves the motor function. The data obtained in this study demonstrate that selective neurotomy in the selected group of patients with severe spasticity who were resistant to conservative therapy provided a positive long-term clinical outcome.

REFERENCES

8. Lorenz F. Uber cirurgische Behandlung der angeborenen spastischen Glie
Medicine often shows the spiral dynamics of evolution as it constantly uses the techniques that have been proposed several tens or even hundreds years ago. Indeed, the results of the methods that have seemed to be old and well-known get to a new level when modern equipment, microsurgical instruments, and new materials are used. Thus, complete cutting of nervus obturatorius in order to manage adduction contractures in patients with central spastic paralysis was described by R. Selig as early as in 1913. Destruction of the posterior branch of nervus obturatorius is now used to treat the pain syndrome associated with coxarthrosis, while selective neurotomy of this nerve is employed to treat spasticity of the adductor muscles of the hip.

The authors should be given credit as they use all the methods for treating spasticity in this group of patients, which is very complex to manage, including chronic stimulation of the spinal cord, intrathecal baclofen therapy, posterior selective rhizotomy, and selective neurotomy. Thus, the present study is one of the fragments of comprehensive, complex, and meticulous work. Nevertheless, it would be good to hear the authors’ opinion regarding the choice methods (if there are any) and choice criteria for selecting a certain procedure for treating spasticity. The authors cite only English-language papers; however, this issue is being studied in Russia as well. Thus, speaking about the use of DREZ-tomy and selective rhizotomy in patients with spastic and pain syndromes, we reported the results and potential of these methods in a series of studies published in 2007—2008.

The pathogenetic mechanism of action of selective neurotomy has not been elucidated, since a partial cut of the motor portion of the reflex arc has no effect on the source of pathologically increased agitation that causes a spastic syndrome, as opposed to selective partial rhizotomy of the posterior roots, which reduces activity of the source of this agitation.

Good outcomes that have been statistically verified were obtained in this study. The amount of clinical data is not large yet. However, taking into account the long-term catamnesis followed up by the authors it would be of interest to know whether these results are long-lasting, since the rate of positive outcomes of treating both the spastic and pain syndromes are known to decrease with time when any therapy procedure is used.

It is a well-known fact that there is a risk of development of the neuropathic pain syndrome after neurotomy (even selective one) of mixed nerves. Time will show whether the modern procedures used by the authors allow one to avoid it. Nevertheless, good outcomes have been obtained so far. This fact gives grounds for being optimistic about using selective neurotomy for the selected group of patients with spastic syndrome.

O. N. Dreval’, A. V. Kuznetsov (Moscow)