Medical
Research
Journal

DIAGNOSTIC CAPABILITIES OF LOW-FIELD MRI IN THE DETECTION AND CHARACTERIZATION OF PRIMARY AND SECONDARY BRAIN TUMORS

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Abstract. Brain tumors remain a major cause of morbidity and mortality worldwide. High-field MRI is considered the gold standard for neuro-oncological diagnostics; however, its availability is limited in many regions. This study aimed to evaluate the diagnostic capabilities of a low-field 0.2 T MRI system in detecting and characterizing intracranial tumors and to compare the findings with CT data. A retrospective analysis of 14,570 brain examinations performed between 2000 and 2009 identified 678 space-occupying lesions (4.7%). Gliomas, metastases, and meningiomas were the most common tumors. Low-field MRI demonstrated high sensitivity in detecting tumor heterogeneity, cystic degeneration, necrosis, hemorrhage, and contrast enhancement patterns, which were critical for tumor grading. Dynamic contrast-enhanced MRI improved differentiation between benign and malignant tumors. The results indicate that low-field MRI is a valuable, cost-effective tool for neuro-oncological diagnostics, particularly in resource-limited settings.

Keywords: brain tumors, low-field MRI, glioma, meningioma, metastasis, neuroimaging, contrast enhancement.

ДИАГНОСТИЧЕСКИЕ ВОЗМОЖНОСТИ НИЗКОПОЛЬНОЙ МРТ В ВЫЯВЛЕНИИ И ХАРАКТЕРИСТИКЕ ПЕРВИЧНЫХ И ВТОРИЧНЫХ ОПУХОЛЕЙ ГОЛОВНОГО МОЗГА

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Аннотация. Опухоли головного мозга остаются одной из ведущих причин инвалидизации и смертности. Высокопольная МРТ является «золотым стандартом» диагностики, однако ее доступность ограничена. Целью исследования было изучить диагностические возможности низкопольной МРТ (0,2 Т) при опухолях головного мозга и сравнить результаты с данными КТ. Ретроспективный анализ 14 570 исследований выявил 678 объемных образований (4,7%). Наиболее часто встречались глиомы, метастазы и менингиомы. Низкопольная МРТ позволила выявить структурную неоднородность опухолей, зоны некроза, кровоизлияния и особенности контрастирования. Динамическое контрастное усиление улучшило дифференциальную диагностику доброкачественных и злокачественных опухолей. Низкопольная МРТ может рассматриваться как экономически эффективный метод нейровизуализации в условиях ограниченных ресурсов.

Ключевые слова: опухоли головного мозга, низкопольная МРТ, глиома, менингиома, метастазы, нейровизуализация.

PAST MAGNIT QUTBLI MRT NING MIYA O‘SMALARINI ANIQLASH VA TAVSIFLASHDAGI DIAGNOSTIK IMKONIYATLARI

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Annotatsiya. Miya o‘smalari butun dunyoda nogironlik va o‘limning asosiy sabablaridan biri bo‘lib qolmoqda. Yuqori magnit qutbli MRT neyroonkologiyada oltin standart hisoblanadi, ammo ko‘plab hududlarda uning mavjudligi cheklangan. Ushbu tadqiqotning maqsadi 0,2 T past magnit qutbli MRT ning miya o‘smalarini aniqlashdagi diagnostik imkoniyatlarini baholash va KT bilan solishtirish edi. 2000–2009 yillarda o‘tkazilgan 14 570 MRT tekshiruvlarining retrospektiv tahlili natijasida 678 ta hajmli shakllanish aniqlangan (4,7%). Eng ko‘p uchragan o‘smalar gliomalar, metastazlar va meningiomalar bo‘ldi. Past maydonli MRT o‘smalarning geterogenligi, nekroz, qon ketish va kontrastlanish xususiyatlarini aniqlash imkonini berdi. Dinamik kontrast MRT yaxshi va yomon sifatli o‘smalarni farqlashda muhim ahamiyatga ega. Past qutbli MRT resurslari cheklangan sharoitlarda samarali diagnostik vosita hisoblanadi.

Kalit so‘zlar: miya o‘smalari, past qutbli MRT, glioma, meningioma, metastaz, neyrotasavvur.

Introduction. According to epidemiological data, in Uzbekistan, the proportion of primary brain tumors (PBT) among all cases of malignant neoplasms in adults is 2%, with an incidence of 8 per 100,000 [12, 14, 15], while in the Republic of Kazakhstan it is 5.3 per 100,000 population [2]. In the age group under 65, cerebral gliomas are the fifth leading cause of death among malignant neoplasms [5, 6], and in children, the second (15–25%), and are the most common solid tumors. In 40% of cases, they are represented by gliomas, in 25% by medulloblastomas, and less commonly by germ cell tumors and craniopharyngiomas. The five-year survival rate of children with PBT is higher than that of adults and is 59% in the UK and 72% in the USA [15]. The average survival rate for astrocytomas is 7 years, for anaplastic astrocytomas - 1-1.5 years, and for glioblastomas - from 9 to 11 months [12]. The average life expectancy of patients with malignant gliomas is 11.5 months, with metastases - 5.8 [3]. Brachytherapy can improve the survival of patients with inoperable brain tumors. Mortality in craniotomies for malignant gliomas and metastases reaches 5%, and in stereotactic interventions - 1%. Symptomatic meningiomas account for 13-25% of all primary brain tumors. Depending on the degree of malignancy, meningiomas proper (grade I), atypical meningiomas (II), anaplastic meningiomas (III), and meningiosarcomas (IV) are distinguished. The widespread introduction of X-ray computed tomography (CT), contrast-enhanced CT (CE CT), magnetic resonance imaging (MRI), dynamic contrast-enhanced MR (DCE MR), and MR angiography into clinical practice has significantly increased the detection rate of brain tumors [2, 9, 10, 11, 13]. Neuroimaging data do not allow an accurate assessment of tumor morphology; therefore, ultrasound-guided stereotactic biopsy and CT, MRI, and PET are of great importance for determining treatment tactics and prognosis. However, not all medical institutions have high-tech, expensive neuroimaging equipment. Studying the capabilities of less expensive MR scanners with a magnetic field induction of 0.2–0.4 T in the diagnosis of brain pathology is of great practical and economic importance. The aim of our study was to thoroughly investigate the capabilities of a low-field 0.2 T Siemens Magnetom open (Germany) MRI scanner in brain tumor diagnostics and compare the results with CT data. A total of 14,570 brain examinations were performed between 2000 and 2009, and 678 (4.7%) space-occupying lesions were detected (Table 1).

Table 1. Number of Detected Space-Occupying Lesions and Pituitary Diseases by Year

Examinations	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Total examinations	864	1186	1466	1388	1484	1443	1134	1959	2065	1581
Space-occupying lesions	69	98	82	64	77	64	46	63	64	51
Percentage (%)	8.0%	8.3%	5.6%	4.6%	5.2%	4.4%	4.1%	3.2%	3.1%	3.2%
Pituitary diseases	26	45	67	68	82	60	48	62	80	69
Percentage (%)	3.0%	3.8%	4.6%	4.9%	5.5%	4.2%	4.2%	3.2%	3.9%	4.4%

Of the patients examined, 359 (53.0%) were men and 319 (47.0%) were women. The age of the patients ranged from 3 to 83 years (mean 43 years). Meningiomas predominated at the age of

40-60 years, more often detected in women; brain metastases - at the age of 45-75 years with equal frequency in men and women, neuroepithelial - at the age of 3 to 50 years, more often in males. Of the nosological forms among the space-occupying formations of the brain identified during the examination (Table 2), the following were encountered: intracerebral - neuroepithelial (astrocytomas, oligodendrogliomas, ependymomas, tumors of the choroid plexus) and metastases, as well as tumors of the meninges - from the meninges, non-meningothelial and of unknown origin.

Table 2. Types of Diagnosed Space-Occupying Brain Lesions

Nosological Forms	Absolute Number (n)
Neuroepithelial tumors	349
Metastases	156
Tumors of the brain meninges (meningiomas)	183

All patients underwent MRI of the brain using the standard tomograph program developed by Siemens. MSME and MSSE sequences for obtaining T2 and T1 weighted images (WI) were used in all cases, except for patients in severe condition, when these methods were replaced by gradient sequences (GEFI, RARE, RACE, TRAR). Studies with obtaining RD-WI were conducted only in cases of cerebral edema and hemorrhage. The brain was examined in axial, sagittal and coronal projections. Magnevist and Omniscan were used for dynamic contrast. Statistical processing of the results was performed using Microsoft Excel (version 7.0), Statistica (version 5.0) software, correlation analysis and calculation of m and p and were considered reliable for p-cytomas and glioblastomas, most often localized in the frontal [13] and temporal lobes [9]. On MRI, AN ASCs were visualized as formations with a heterogeneous MR signal on T1 and T2 weighted angiograms. In the central parts of the tumor, foci of cystic degeneration were detected in 4 cases. Peritumoral edema in the form of an increased MR signal of a characteristic diverging beam shape was diagnosed in 12 cases. Intense contrast enhancement was typical for anaplastic astrocytomas. Glioblastoma (GB, 40 cases) is the most malignant of all glial OCGMs and is characterized by a rapid increase in clinical symptoms due to increased intracranial pressure and the appearance of brain wedging symptoms. MRI revealed significant tumor heterogeneity: on T1 weighted angiogram, a formation with a mixed hypo- and iso-intensive MR signal and central necrosis; on T2 weighted angiogram, hypo-, iso-, and hyperintensive signals from the GB stroma, necrosis, cysts, and hemorrhages. GB often (32 cases) spread to the other hemisphere. For benign diffuse ASCs, the most characteristic feature on CT is a low-density zone without clear boundaries with the surrounding brain tissue. CT with intravenous administration of Ultravist was not accompanied by an increase in tumor density. Petrifications in the form of small and larger foci were often observed (48 cases), which is consistent with the data of M. Castillo, J. Scattiff, T. Boulchiu (1992). In malignant transformation of astrocytomas, zones of contrast agent accumulation were determined inside the benign tumor (2 cases). On CT, anaplastic astrocytomas were defined as a non-homogeneous tumor with mixed density. After contrast administration, tumor heterogeneity significantly increased. Areas of increased density often had the appearance of rings and semirings, inside which there were areas of low density - cysts, which is consistent with the data of other authors [9, 11, 12, 13]. On CT, the density of the GB was heterogeneous: the central zone was necrotic and low-density, petrification was observed in 3 cases, and hemorrhage into the tumor was observed in 4 cases. The tumor was typically surrounded by perifocal edema. On CT with C-enhanced contrast, the contrast appeared as a ring with a non-uniform inner contour. Gliosarcoma was detected in 2 cases. On CT, the tumor resembled a meningioma surrounded by perifocal edema. CT with CE revealed heterogeneous ring-shaped enhancement consistent with the tumor location. On CT, pilocytic astrocytoma was visualized as a well-demarcated, round or oval-shaped mass with hypo- or isodense characteristics. CT showed more clearly defined petrifications, and the solid tumor appeared homogeneous. According to our data, the most characteristic MR diagnostic criteria for benign gliomas were clear margins, the absence of peritumoral edema, the presence of cysts, and slow and polyfocal contrast enhancement. The tumor was noted to exhibit slow contrast enhancement (90%). The study demonstrated that fibrillary and protoplasmic astrocytomas (70 cases) showed moderately hyperintense signals on axial T2-weighted images and appeared hypointense on coronal T1-weighted images. Pilocytic astrocytomas (20 cases) were typically located in the white matter, close

to the ventricular walls, and did not extend to adjacent brain lobes. On axial T2-weighted images and coronal T1-weighted images, the tumor was isointense relative to the brain structure and often contained a cyst, which was hyperintense on T2-weighted images and isointense on T1-weighted images. Calcifications were detected in 3 cases. Oligodendrogliomas were present in 17 patients and were localized primarily in the frontal and temporal lobes. In 4 cases, large tumors caused displacement of midline structures and were accompanied by peritumorous edema. The tumor structure was heterogeneous due to the presence of calcifications. During dynamic MR contrast enhancement of benign gliomas, absent or delayed and weak polyfocal contrast enhancement was most often observed (90%). In 9 cases, weak peripheral contrast enhancement or its absence was observed. As a rule, as gliomas malignantly transform, their structural homogeneity changes due to necrotic edema and hemorrhage; therefore, the MR signals from these tumors were heterogeneous in our studies. The constant criteria for MR diagnostics of AN ASC and GB are structural heterogeneity, blurred contours, and pronounced perifocal edema. Contrast enhancement was polyfocal in most cases, less peripheral, and resolved more quickly than in benign gliomas. Ependymoma was diagnosed in 2 cases. The tumor was localized in the frontal lobe of a 27-year-old pregnant woman. Native CT revealed a large lesion with perifocal edema. The tumor had moderately increased density with areas of decreased density (due to cysts). Brain metastases were diagnosed in 156 patients over 60 years of age (85 men, 71 women). The main sources were lung, breast, kidney, and thyroid cancer. Solitary metastases were diagnosed most frequently (80%), while multiple metastases were less common (18%). Areas of necrosis and hemorrhage were present in the metastases. Perifocal edema was characteristic of most metastases. On CT, most metastases had low density, with only hemorrhagic, calcified, and high-protein inclusions exhibiting increased density. On CT with DCE, a ring-shaped enhancement (the "corona effect") was observed, which is explained by the presence of necrosis or a cyst in the tumor center and abundant vascularization at its periphery. MRI with DCE is more informative than CT in diagnosing brain metastases. Metastases are better visualized on T2-weighted images and must be differentiated from malignant gliomas, abscesses, granulomas, parasitic cysts, meningiomas, and 8th-brain neurinomas. Meningiomas of the cerebral hemispheres: among 183 patients with convexital meningiomas, 117 were localized in the temporal lobe, 28 in the frontal lobe, 28 in the parietal lobe, and 10 in the occipital lobe. The most significant MRI features of meningiomas are clear margins, structural homogeneity, the presence or absence of perifocal edema, contrast accumulation for up to 3-4 minutes, and homogeneous contrast enhancement. As a rule, meningiomas had clear margins on MRI and yielded homogeneous-isointense MR signals in T1 and T2 weighted angiograms. Pronounced hyperintense peritumoral edema in T1 weighted angiograms and heterogeneity of tumor signals (except for hypointense calcifications) were observed in large tumors and in cases of malignancy (morphological confirmation in 4 cases). Significant displacement of midline structures was observed in large tumors. In 8 cases, the tumor was closely associated with the adjacent bones, and the dura mater was denser, which is consistent with the data of other authors [5]. With MRI with CU, due to the rich vascularization of the meningioma, in all cases within the first seconds, rapid and homogeneous accumulation of contrast in the tumor was noted (signal intensity - 275 ± 2.3%). CT with CU had high specificity (98%), sensitivity (98%) and accuracy. During the period 2000-2009, 607 patients were examined for pituitary diseases - 257 (42.47%) men and 30 (57.6%) women (Table 1). The age of patients ranged from 6 to 77 years (average 46 years). Of the identified diseases, the majority were pituitary anomalies, namely, an "empty" sella turcica (62.2%) and adenomas — micro- and macroadenomas (37.8%). In patients with pituitary macroadenomas, especially with suprasellar growth, an oval or round formation, hyperintense on axial T1WI, was detected in the projection of the sella turcica. The appearance of heterogeneous signals was associated with the presence of areas of necrosis, hemorrhage, or cysts in the tumor (20-30%). Pituitary macroadenomas usually weakly and homogeneously contrasted on average after 4-6 minutes, with a saturation peak of up to 82% ± 3.9 and were localized most often (in 32) in the anterior parts of the pituitary gland in the form of foci, hyperintense on axial T2WI against a background of isointense gland tissue. With MRI with CU, all microadenomas were detected with signal enhancement 4-6 minutes after the start of contrast. Craniopharyngiomas were detected in 17

men and 19 women aged 9 to 29 years. All cases had supra- and parasellar tumor extension, fuzzy margins (91%), heterogeneous structure (100%), and peripheral enhancement (77%). On MRI, craniopharyngiomas were visualized as cystic lesions with a heterogeneous structure. The tumors most often had a small-locular structure and a characteristic "mottled" appearance. The presence of hypointense calcifications on T1 and T2 weighted images was observed in 8 cases. The cystic tumor contents appeared hyperintense on T2 weighted images and hypointense on T1 weighted images in coronal and sagittal sections. Craniopharyngiomas were clearly visible on craniograms and linear tomograms of the skull.

Conclusion. This study demonstrates that low-field magnetic resonance imaging (MRI) with a magnetic field induction of 0.2 T provides clinically meaningful diagnostic information in patients with primary and secondary brain tumors, particularly in settings with limited access to high-field neuroimaging technologies. The analysis of 14,570 brain examinations over a ten-year period revealed a prevalence of space-occupying intracranial lesions of 4.7%, with gliomas, metastases, and meningiomas representing the dominant pathological entities. The MRI signal characteristics of benign and malignant gliomas showed significant differences in structural homogeneity, contrast enhancement patterns, perifocal edema, and contour clarity, which allowed reliable differentiation between low-grade and high-grade tumors. Low-field MRI was particularly effective in detecting cystic components, necrotic zones, hemorrhages, and calcifications, although CT remained superior for the visualization of petrifications and bone involvement. Dynamic contrast-enhanced MRI significantly improved tumor characterization, especially in differentiating metastases, glioblastomas, and meningiomas, demonstrating high diagnostic sensitivity and specificity. The study confirmed that structural heterogeneity, blurred margins, and pronounced perifocal edema are constant radiological criteria of high-grade gliomas, whereas benign gliomas exhibit clear margins, slow polyfocal contrast accumulation, and minimal perifocal edema. Meningiomas were characterized by homogeneous contrast enhancement and clear tumor boundaries, while pituitary adenomas and craniopharyngiomas exhibited typical localization patterns and contrast dynamics. The findings indicate that low-field MRI can serve as a cost-effective and diagnostically reliable neuroimaging modality for brain tumor detection and characterization in resource-limited healthcare systems. Integration of low-field MRI with CT and stereotactic biopsy can optimize diagnostic algorithms, improve treatment planning, and enhance prognostic assessment in neuro-oncology practice.

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