Srp Arh Celok Lek. 2016 Mar-Apr;144(3-4):158-164
ОРИГИНАЛНИ РАД / ORIGINAL ARTICLE
DOI: 10.2298/SARH1604158S
UDC: 616.831-005.1-06

Ability to solve riddles in patients with speech and language impairments after stroke

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SUMMARY

Introduction Successful riddle solving requires recognition of the meaning of words, attention, concentration, memory, connectivity and analysis of riddle content, and sufficiently developed associative thinking.

Objective The aim of the study was to determine the ability to solve riddles in stroke patients who do or do not have speech and language disorders (SLDs), to determine the presence of SLDs in relation to the lesion localization, as well as to define the relationship between riddle-solving and functional impairment of a body side.

Methods The sample consisted of 88 patients. The data used included age, sex, educational level, time of stroke onset, presence of an SLD, lesion localization, and functional damage of the body side. The patients were presented with a task of solving 10 riddles.

Results A significant SLD was present in 38.60% of the patients. Brain lesions were found distributed at 46 different brain sites. Patients with different lesion localization had different success in solving riddles. Patients with perisylvian cortex brain lesions, or patients with Wernicke and global aphasia, had the poorest results. The group with SLDs had an average success of solved riddles of 26.76% ($p = 0.000$). The group with right-sided functional impairments had average success of 37.14%, and the group with functional impairments of the left side of the body 56.88% ($p = 0.002$).

Conclusion Most patients with SLDs had a low ability of solving riddles. Most of the patients with left brain lesions and perisylvian cortex damage demonstrated lower ability in solving riddles in relation to patients with right hemisphere lesions.

Keywords: localized brain damage; associative thinking; aphasia; functional impairment

INTRODUCTION

Stroke is the most common cause of severe physical disability, impaired communication skills, limited ability to perform activities of independent living, dependence on others for care and assistance, and many other more or less serious consequences [1]. Ageing of population, globalization, and urbanization are the powerful drivers of the stroke epidemic [2, 3]. The World Health Organization has forecasted that by 2050, the number of people 60 years of age and older will reach two billion [4].

The human brain consists of a large number of neural networks, which connect many functional regions of the brain. Damage to these networks is the result of a stroke. The location of brain damage determines the type of dysfunction that results. Verbal communication impairment is a particular problem in stroke patients. Difficulties may occur in speech and language understanding or expression, or both understanding and expression.

There is a large amount of information in the world today about speech and language impairments as a result of stroke. It is assumed that the entire cortex is involved in connecting linguistic functions.

Clinical data show that lesions in certain areas of the brain give rise to severe speech and language disorder (SLD), while damage to other areas of the cortex does not cause speech and language disorders [5, 6, 7]. Both cerebral hemispheres are necessary in order for the brain to function properly. Certain functions are better executed by the right hemisphere of the brain while others are better executed by the left hemisphere. This phenomenon is known as the functional asymmetry of the brain [8].

Processes and activities of certain brain regions related to speech and language communication are rarely present in both hemispheres. For most people, the left half of the brain is responsible for speaking, reading and writing. The role of the right hemisphere and sub cortical zone in executing these functions is less known.

Lexical and grammatical knowledge show hemispheric specialization. Speech and language functions are predominantly left hemisphere functions in most people. Right hemisphere has a role in understanding prosody (the color and tonality of verbal statements), but it has no role in processing grammatical relations. Right hemisphere is important for learning a new language, learning new words, for spatial organization and attention [9].

Damage to the brain's sensory and motor pathways and centers often cause delays, dif-

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ficulties or total loss of adequate response of the patient. Damage to these functions depends on the location, intensity and extent of brain lesions.

In our previous research, we have found brain damage almost equally located on the left and right sides of the brain, to a lesser extent on both sides. About a third of all brain damage, located mainly in the left hemisphere, was accompanied by an SLD. SLDs are less common as a result of damage to the right hemisphere [10].

Damage to the right cerebral hemisphere in most patients does not have an SLD as a consequence. Very few studies explore the implications for understanding speech after damage to the right cerebral hemisphere. Nomination is a problem that arises with disorders of higher cognitive functions due to its interconnection with language and memory. This problem occurs in all types of aphasia caused by focal injury and neurodegenerative diseases.

We investigated nomination ability in 105 patients who had an SLD after stroke. We found that the lesions are located in the left brain hemisphere in 58.49% of the sample, they were bilateral in 29.24% of the sample (which includes damage to the left side of the brain), they were in the right brain hemisphere in 4.71% of the sample, and the unknown location was in 7.54% of the patients. Patients with lesions on the right hemisphere had more success and produced better results when compared to patients with left brain hemisphere lesions [11].

Successful naming depends on the ability of the auditory understanding of the message, the visual perception of the object that shall be appointed, on the level of short-term and long-term memory, attention and concentration, as well as the capacity for verbal expression. Damage to one or more of these skills leads to lower success in tests of naming [1].

Riddles are statements, questions, and phrases that have double or veiled meaning, and set as a task to be solved or guessed.

From the standpoint of neurofunctional anatomy there are several reasons for the failure of solving language problems on the part of patients with stroke.

Partial or complete absence of understanding speech and linguistic messages is the result of damage to the primary acoustic areas (transverse temporal gyrus and planum temporal) and secondary acoustic areas of the dominant hemisphere [12]. The planum temporale shows a significant asymmetry. In 65% of all individuals the left planum temporale appears to be more developed, while the right planum temporale is more developed in only 10%. In some individuals' brains, the planum temporale is more than five times larger on the left than on the right, making it the most asymmetrical structure in the brain [13].

Understanding depends on the size and localization of damage to neuroanatomic bases and linguistic complexity of the set task.

Prosodic elements of speech (intonation, register, tempo, rhythm, intensity, and accent) provide the non-dominant hemisphere with information needed for understanding ambiguous messages, metaphor, sarcasm, humor, and even riddles. Damage to the area of the non-dominant hemisphere needed for this task complicates the analysis of the prosodic elements of speech.

Damage to the lower part of the primary motor area, Broca's area of the dominant hemisphere (pars opercularis, pars triangularis, inferior frontal gyrus) and the premotor area, results in impaired speech, motor aphasia [12]. With more extensive damage the patient knows what he wants to say but cannot, while lesser damage results in vague and unintelligible speech.

Reduced ability or inability to complete the integration of information, and their inter-media processing, is the result of damage to the associative areas of the cerebral cortex.

The products of inter-media information processing in neural networks associative cortex and the limbic system are complex functions such as thinking, language, selective attention, memory, and other forms of cognitive activity and behavior [14].

Damage to several brain sites responsible for speech and language functioning significantly complicates understanding and processing of linguistic messages. This reduces the chances of getting expected verbal responses.

In our previous study, we tested the success of solving 42 riddles in patients with right-sided brain lesions after stroke and in the "healthy population" control group [1].

For this study we used 10 riddles for which the "healthy population" control group had an average success rate of 89.50% [1].

OBJECTIVE

The aim of the study was to determine the ability to solve complex speech and language structures, riddles, in patients with or without history of SLDs. Further objective of the study was to determine the presence of an SLD in relation to brain lesion localization, and relation between riddle-solving ability and body side impairment in the same patients.

METHODS

The sample consisted of 88 patients involved in rehabilitation at IPRM Dr Miroslav Zotović in Banja Luka, during the period from June 1, 2014, to July 31, 2014.

The information collected includes data on age, gender, educational level, time of stroke onset, presence of an SLD, brain lesion localization and functional damage of body side. Patients were tested within 90 days of surviving the stroke. Assessment of SLD type was performed in patients who were referred by a physiatrist.

We read 10 riddles to each patient. The patient needed to solve each riddle within 90 seconds. We compared the performance results of patients with and without an SLD, with different brain lesions, with different types of SLD, and with functional impairments of the right and left side of the body.

RESULTS

The average age of the sample was 69.46 ± 9.73 years. Gender structure was 59.10:40.90% (N = 52:36) in favor of males. The average age of males was 67.92 years, and 71.69 years in female patients (Graph 1).

The education level of the group was as follows: 49 with no qualifications (55.68%); 25 workers with an apprenticeship qualification (28.40%); seven with high school education (7.95%); and seven with a higher degree of education (7.95%).

The average number of days from onset stroke to testing for the entire sample was 48.03.

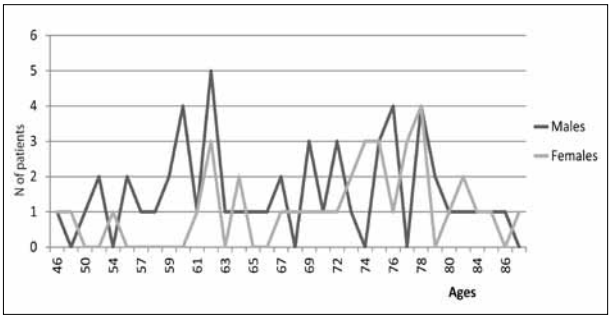
Average of the entire group was 4.71 successfully solved riddles, or 47.10%. The average success of the group with an SLD was 26.76% of successfully solved riddles, and 60.00% for the group without an SLD (Table 1).

T-test for equality of means of success of patients with and without an SLD shows that the results are statistically significant (p = 0.000).

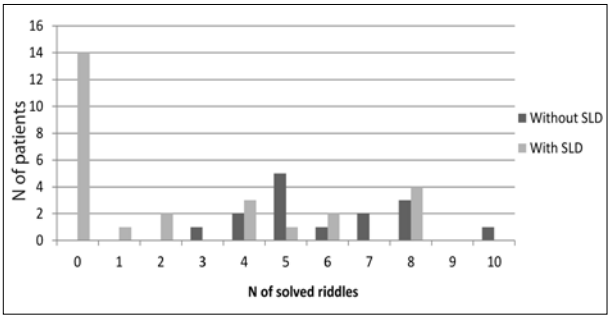
T-test for equality of means of success of patients with functional impairments of the right and left side of the body shows that the results are statistically significant (p = 0.002).

We found that 47.70% of the sample had right-sided body impairments, 51.1% had left, and 1.10% of patients were those with bilateral functional impairments of the body occurring as a result of a stroke.

We found that of the 45 patients with functional impairments of the left side of the body, seven (15.55%) had significant SLD. Of the 42 patients with functional impairments of the right side of the body, 27 (64.28%) had an SLD present. One patient with bilateral functional body impairments had no significant SLD.



Graph 1. Gender and age structure of the sample



Graph 2. Number of successfully solved riddles in relation to functional impairment of the right side of the body in patients with and without an SLD

The average success of the group with right-sided functional impairments was 37.14% of solved riddles (Graph 2). The group with functional impairments of the left side of the body had success in 56.88% of the test, p = 0.002 (Graph 3).

In the group of 42 patients with functional impairments of right side of the body, there were 27 (64.28%) patients with an SLD which significantly affected the result. We found that in the group of 45 patients with functional impairments of the left side of the body there were seven (15.55%) patients with an SLD which significantly affected the result.

Patients without an SLD were on average 68.12 years old (±9.80), and average age of patients with an SLD was 71.58 years (±9.37), p = 0.102.

The correlation between the number of days passed from the stroke and success in riddle solving was r = 0.025, p = 0.816.

The correlation between age and success was r = 0.402, p = 0.000.

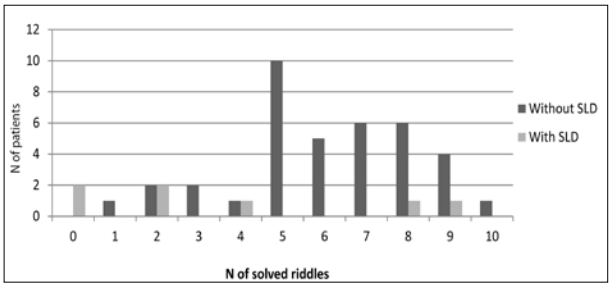
DISCUSSION

The ability of auditory perception, analysis, understanding, remembering, connecting analogies and associations of previously learned language structures, are all associated with the functioning of the entire brain, especially the parts responsible for speech and linguistic functioning. Providing 'workarounds,' indirect associative information about a term that needs to be nominated, is the essence of each given riddle [1].

Successful riddle resolving requires good command of the language, recognition of the meaning of words in the riddle, attention, concentration and memory, perception of speech and language content as a whole, as well as developed associative thinking.

Absence of any of the above stated elements will result in insufficient understanding of set riddles or complete lack thereof, and the absence of adequate response.

We wanted to determine the difference in performance between patients with and without an SLD in solving complex linguistic structures expressed through riddles. Using the same test we also wanted to determine the difference in performance among patients with different brain lesions, with different types of SLD and with functional impairment of a body side.



Graph 3. Number of successfully solved riddles in relation to functional impairment of the left side of the body in patients with and without an SLD

doi: 10.2298/SARH1604158S

Patients had a task of solving 10 riddles. We took the riddles from ABC books and textbooks used in educational programs starting from primary school from the time when the largest number of respondents attended primary school.

The average age of the sample (Graph 1) was similar to our previous researches [1, 10, 11, 15].

In the researched sample test results ranged from complete ineffectiveness to complete success (Table 1). Low success of the group with an SLD was associated with brain damage of the regions responsible for speech and language functioning. Patients with damage to these sites had little or no auditory comprehension, connecting, had anomie, problems of verbal expressions, etc. In our previous study, we analyzed success in solving riddles in "healthy population," and performance varied depending on the riddle, from 85% to 100%, the average being 89.50% [1]. Patients without an SLD achieved low results in relation to "healthy

Table 1. Successfully solved riddles in relation to brain lesion localization

Localization of stroke	Mean of solved riddles	No. of patients	Std. Deviat.	No. without SLD	No. with SLD
Multifocal hotspot dominant left	0.00	1	-	0	1
Paraventricular left	0.00	1	-	0	1
Parietal and paraventricular left	0.00	1	-	0	1
Parietal-occipital-temporal left	0.00	1	-	0	1
Parietal-temporal left	0.00	3	0.00	0	3
Frontoparietal left	0.00	2	0.00	0	2
Parietal and paraventricular right	1.00	2	1.41	1	1
Multifocal hotspot dominant right	2.00	1	-	0	1
Temporal left	2.00	1	-	0	1
Frontal-parietal-temporal right	2.50	2	3.53	1	1
Periventricular left	2.75	4	2.21	0	4
Parietal right	3.75	4	2.50	3	1
Parietal left	4.00	1	-	0	1
Parietal right and paraventricular bilateral	4.00	1	-	1	0
Pons	4.00	1	-	1	0
Temporal-occipital left	4.00	2	5.65	0	2
Basal ganglia left	4.50	4	4.12	2	2
Frontal-parietal right	4.66	3	1.52	3	0
Multifocal hotspots	4.75	8	3.24	5	3
Unknowns localization	4.75	4	1.70	3	1
Supra and infratentorial right	5.00	1	-	1	0
Frontal left	5.00	3	1.00	3	0
Thalamus right	5.00	1	-	1	0
Periventricular right	5.00	1	-	1	0
Basal ganglia right	5.50	4	3.41	4	0
Parietal-temporal right	5.50	2	0.70	2	0
Supratentorial left	5.50	2	0.70	2	0
Supratentorial and parietal right	5.50	2	4.94	1	1
Capsule internal and basal gang. right	6.00	1	-	1	0
Fronto-parietal-insular left	6.00	1	-	0	1
Periventricular bilateral	6.00	1	-	1	0
Irrigation ACM right	7.00	2	4.24	1	1
Paraventricular right	7.00	1	-	1	0
Parietal bilateral	7.00	1	-	1	0
Parietal and insular right	7.00	1	-	1	0
Pons right	7.00	1	-	1	0
Fronto-parietal-temporal left	7.00	2	1.41	0	2
Thalamus left	7.00	3	3.60	2	1
Supratentorial right	7.66	3	0.57	3	0
Basal ganglia both side	8.00	1	-	1	0
Putamen left	8.00	1	-	1	0
Cerebellum left	8.00	1	-	1	0
Fronto-parietal bilateral	8.00	1	-	1	0
Centrum semi oval bilateral	8.00	1	-	1	0
Paraventricular bilateral	8.50	2	0.70	1	1
Capsule internal right	9.00	1	-	1	0
Total	4.71	88	3.02	54	34

population," probably because of problems with attention, concentration, low integration of obtained data and other reasons that should be researched.

Kirshner [16] found that language function lateralizes to the left hemisphere in 96–99% of right-handed people and in 60% of left-handed people. Of the remaining left-handed people, about one half have mixed hemisphere language dominance, and about one half has right hemisphere dominance. Left-handed individuals may develop an SLD after a lesion of either hemisphere, but syndromes from a left hemisphere injury may be milder or more selective than those seen in right-handed individuals [16].

Knecht et al. [17] found that in most people the left side of the brain contains language centers. The incidence of right hemisphere language dominance was found to increase linearly with the degree of left-handedness, from 4% in strong right-handers to 15% in ambidextrous individuals, and 27% in strong left-handers [17].

In our research, brain lesions are found distributed in 46 different brain sites (Table 1). Localizations that are specified in this research are listed as there were mentioned in CT and NMR reports taken from the medical records. The term "multifocal hotspots" includes, not only the focally distributed lesions in a certain location, but also lesions that were distributed in different combinations on three or more unrelated brain sites.

Patients with different lesion localization had different success in solving riddles.

Patients without an SLD mainly had right brain lesions. Only small number of patients had no SLD in the part of the sample with lesions of the left hemisphere of the brain. They had brain lesions located in the deeper layers that are not responsible for speech and language. Why the success of the group with right brain lesions is not approximately equal to the "normal population" should be researched in a separate study.

We assume that there are several factors that have contributed to these low results. The level of attention, concentration, lack of motivation, and damaged prosodic elements of speech and language reduce the ability to understand idioms, sarcasm, and humor, as well as riddles, and probably some other factors have also influenced the results.

Causes for these low results can be found in patients with an SLD.

Lesions of posterior locations, behind the lateral sulcus, temporal lobe and crossing points of temporal-parietal lobe of the left cerebral hemisphere, result in reduction or complete absence of speech and language understanding.

Damage to the front of the lateral sulcus, lesions of the frontal lobes, have resulted in reduction or complete absence of speech expression. Some of these patients may have and could give the correct answer, but due to impaired function of initiation they were prevented to find an adequate expression, or demonstrated an inability to name.

Associative cortex lesions result in the inability to connect more information or integrate them, or to process them mentally and solve the problem, as in this case, i.e. to solve riddles.

Greater damage to multiple brain sites responsible for speech and language processes reduced the possibility of successful riddle solving due to more extensive speech and language functions' impairment.

In the group of patients without SLDs there were 44 patients (81.48% of the group) with five or more successfully solved riddles, while the group with SLDs had nine patients (26.47% of the group) with five or more successfully solved riddles (Table 1).

There were seven patients in the group without SLDs (12.96% of the group) with eight or more successfully solved riddles. Group with SLDs had one patient (2.94% of the group) with eight or more successfully solved riddles (Table 1).

Average score of seven or more successfully solved riddles achieved one quarter of the sample (22 patients). Seven of these patients had left-sided, six bilateral, and nine right-sided brain lesions (Table 1). Of those, two patients from the group with left-sided lesions had cortical lesions, while others had deep brain lesions. Two of the patients from the group with bilateral lesions had cortical lesions. Most patients in this part of the sample did not have lesions of the sites responsible for speech and language functioning (only five patients from this group had an SLD). The question is why they did not achieve better results than the "healthy population", since 50% of the patients in this group had an average score of seven successfully solved riddles. This is a question for some new, additional research of other factors and circumstances that affect results obtained in this way.

We analyzed the relationship between the type of SLD and the number of solved riddles. The best results were found in patients with dysarthria (Table 2). They were the most numerous in the category of patients with an SLD and successfully solved 61.20% of riddles presented. Most of these patients had no cortical brain lesions. For the most part, patients from this group had no difficulties with understanding the task, with connectivity and processing the riddle, nor with giving an adequate response. The difficulties were present in speech expression and speech fluency.

Patients with Wernicke aphasia, global aphasia and Broca's aphasia had the lowest results. That is the logical consequence of damage to the parts of the brain that are responsible for speech and language understanding, connectivity and processing of riddle elements, as well as localities responsible for the initiation and implementation of an adequate response, or damage to the above mentioned sites in various combinations.

It is interesting that among patients who were not referred to speech therapy assessment, although they had suffered from an SLD in the acute phase of the stroke, nine had a success rate of 0–3 solved riddles. These patients are likely to have other problems such as problems with attention, concentration, memory, connecting information, motivation, presence or absence of psychoorganic syndrome, and the state of premorbid capacity. They probably had no major SLD and were not referred to speech and language assessment.

doi: 10.2298/SARH1604158S

Table 2. Presence of SLDs in relation to their type

No. of solved riddles	Not referred to a speech therapist		Type of SLD in patients referred to a speech therapist					Total
	1*	2*	3*	4*	5*	6*	7*	
0		4	10		1	1		16
1		1		1				2
2	1	2	1	1		1		6
3	2	2						4
4	4			2		1		7
5	12			2		1	1	16
6	5			2		1		8
7	4	3		1				8
8	6	3		5				14
9	1	2		2				5
10	2							2
Total	37	17	11	16	1	5	1	88
Percent	42.04	19.31	12.50	18.18	1.13	5.68	1.13	100.00
Mean of solved riddles	5.91	4.35	0.18	6.12	0.00	3.40	5.00	4.71
Mean of solved riddles	6.00		2.67					4.71

1* – without SLD; 2* – patients not referred to speech therapy assessment although they had SLD in the acute phase of the disease; 3* – global aphasia; 4* – dysarthria; 5* – Wernicke's aphasia; 6* – Broca's aphasia; 7* – aphonia and/or dysphonia

The results of this research in relation to the effects on functional impairment of the body are approximate to those in our earlier study [10].

With this research we confirmed the results of patients with functional impairments on the left side of the body of our previous studies, as the test results are approximately equal to those of this study [1].

This confirms the left hemispheric dominance of speech and language functions. Patients with Wernicke and global aphasia had the worst results.

Most patients with neurological impairments and functional left-sided body, had poor results in solving riddles, even though they did not have brain damage to areas responsible for speech and language functioning.

CONCLUSION

Damage to organic substrate and distribution of neural networks reduces, hinders, slows or completely disables previously developed ability of understanding, associative thinking, memory, attention, concentration, and expression.

Most patients with an SLD showed low ability to solve riddles, but the largest part of the sample, regardless of the localization of brain lesions and body side impairments, had worse results compared to the results of earlier tested "healthy population." Most patients with left hemisphere lesions, with perisylvian cortex damage, had lower results in solving riddles compared to patients with right hemisphere lesions.

ACKNOWLEDGEMENTS

Special thanks for her translation from Serbian to the English language are owed to Ms. Jelena Satara, speech therapist, IPRM "Dr Miroslav Zotović," Banja Luka, Republic of Srpska, Bosnia and Herzegovina.

NOTE

The research was partially presented at the 5th Congress of Physiatrists of Bosnia and Herzegovina with International Participation, Sarajevo, September 25–28, 2014.

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Способност решавања загонетака пацијената са присутним говорно-језичким поремећајима након можданог удара

Горан Савић

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КРАТАК САДРЖАЈ

Увод Успех код решавања загонетака захтева препознавање значења речи, пажњу, концентрацију, краткорочну меморију, повезивање и анализу говорно-језичког садржаја загонетке у целини, те довољно развијено асоцијативно мишљење.

Циљ рада Циљ рада је утврдити успех код решавања загонетака пацијената након можданог удара (МУ), са присутним говорно-језичким поремећајима (ГЈП) и без њих, утврдити присуство ГЈП у односу на локализацију можданог оштећења, те успешност решавања загонетака пацијената у односу на функционално оштећење стране тела.

Методе рада За узорак од 88 пацијената прикупљени су подаци о старости, полу, степену образовања, времену протеклом од МУ, присутности ГЈП, локализацији можданих оштећења, те функционалним оштећењима стране тела. Требало је да пацијенти реше 10 загонетака.

Резултати Значајне ГЈП је имало 38,60% пацијената. Мождане лезије су нађене и распоређене на 46 различитих можданих локалитета. Пацијенти са различитим локализацијама можданих лезија имали су различит успех решавања загонетака. Најслабије резултате постигли су пацијенти са можданим лезијама перисилвијевог кортекса, односно пацијенти са Верникеовом и глобалном афазијом. Просечна успешност групе са присутним ГЈП је била 26,76% решених загонетака (p = 0,000). Просечна успешност групе са десностраним функционалним оштећењима тела је била 37,14% решених загонетака, а групе са левостраним функционалним оштећењима тела 56,88% (p = 0,002).

Закључак Већина пацијената са ГЈП показала је слабу способност решавања загонетака. Већина пацијената са оштећењима леве мождане хемисфере са кортикалним оштећењима перисилвијевог кортекса имала је слабије резултате у решавању загонетака у односу на пацијенте са оштећењима десне хемисфере.

Кључне речи: локализација можданог оштећења; асоцијативно мишљење; афазија; функционална оштећења

Примљен • Received: 07/05/2015 **Прихваћен • Accepted:** 08/06/2015