

## The cognitive functioning of patients with heart disease treated cardiosurgically – assessment before and after surgery. Preliminary study

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### Summary

**Background.** The Coronary Artery Bypass Graft surgery (CABG) serves to improve blood supply to the heart muscle. Better blood supply enhances the improvement of cognitive functioning of people after surgeries. The patients who have undergone these kind of operations are exposed to various unfavorable factors influencing the nervous system, connected, inter alia, with the technique of this type of treatment. Many researchers have suggested the generalized and unspecific deterioration of cognitive functioning in people after CABG.

**Aim.** The aim of the research was to assess the dynamics of the selected cognitive processes (direct visual memory, abstract thinking, verbal fluency) as well as the subjective assessment of own memory in patients qualified to cardiac surgery, and to specify clinical and individual variables which could influence the patients' pre- and postsurgical cognitive functioning.

**Methods.** The studied group consisted of 18 persons (9 women, 9 men), at the age of 55–81 years. The psychological assessment was conducted twice – before and after operation. In psychological assessment the following instruments were used: The Benton Visual Retention Test, verbal fluency test, subtest Similarities (WAIS-R-PL) as well as the Questionnaire of Memory Efficiency by Giovagnoli.

**Results.** The patients achieved better results in majority of cognitive tasks in the second (postoperative) examination, especially significantly in tasks assessing the ability to recollect words according to a given criterion (Animals; Supermarket) as well as the abstract thinking (Similarities).

**Conclusions.** The cognitive functioning of patients who underwent CABG has improved in several days after operation in comparison to their state before treatment. Higher results were noted in tasks involving abstract thinking as well as verbal fluency. Clinical and individual factors modified the patients' results to a various degree.

**Key words:** coronary artery bypass graft (CABG), cognitive functioning, medical neuropsychology

## Introduction

Coronary insufficiency is a source of insufficient blood supply to the brain, which can lead to a variety of brain incidents and the development of cerebral vascular dementia. As a result of hypoperfusion, patients with diagnosed heart failure (regardless of etiology) often develop cognitive, emotional and personality deficits [1, 2]. Cardio-surgical treatment of coronary artery disease by revascularization, that is implantation of aorto-coronary bypass (coronary artery bypass graft, CABG), is one of the ways to improve the blood supply to the heart muscle. Despite the dynamic development of the cardiac surgery, patient subjected to this type of surgery is exposed to the influence of many unfavorable factors associated with the presence of subsequent neuropsychiatric symptoms. Many of these factors are related to the treatment techniques itself [3]. The CABG procedure is performed using extracorporeal circulation (ECC, heart-lung machine), posing a risk of micro- and macro-embolisms or inflammatory response due to the patients' blood contact with the artificial surfaces of the heart-lung machine [1, 3]. The non pulsating blood flow produced by a large part of the extracorporeal circulation pump, hypothermia and anesthetic methods, which are standard practice in this type of treatment, may also have an adverse impact on the CNS functioning. [4, 5]. Qualitative disturbances of consciousness or other neurological and neuropsychiatric complications of acute course persist for several days after surgery with ECC [1, 4, 5, 6].

Despite these negative aspects of the treatment, comparative studies of patients undergoing revascularization with ECC and revascularization conducted on the beating heart (OPCAB, off - pump) have not provided unambiguous conclusions [7, 8, 9]. Beyond the technique of surgery itself, there are other variables negatively affecting the subsequent cognitive resources: non-operational (pre-operative patient's health status, such as hypertension, low ejection fraction, carotid artery stenosis, cerebrovascular disease), preoperative cognitive status, often lower due the vascular burden [1, 10], and sociodemographic factors - advanced age, sex, low level of education [4, 5]. In a distant time after the operation the interaction of these factors may result in impairment of the cognitively efficient patients or aggravate the existing deficits in patients with cognitive disabilities. The specifics and extent of neuropsychiatric symptoms in patients after CABG are discussed. Most frequently they are non-specific in nature, generalized, including disorders of attention, memory, learning, psychomotor speed, abstract thinking, rarely they are associated with focal brain pathology or TIA. Neuropsychological symptoms are characterized by their tendency to gradually withdraw [4, 5], consolidate [11], or improve the results compared to the preoperative study [5]. Diversity of research results is related to the use of different neuropsychological assessment techniques [12], different time intervals between the measurements, psychological (emotional state) and perioperative factors (pain, fatigue, lack of sleep, the effect of previously used drugs) [10, 13] and their interactions [4, 5].

## Material

In the studies selected aspects of cognitive functioning of patients treated with CABG were analyzed, i.e. direct visual memory, abstract thinking, verbal fluency,

subjective evaluation of the functioning of one own memory. The aim was to compare the level of performance of cognitive tasks from preoperative phase and from early phase after surgery (7<sup>th</sup> -8<sup>th</sup> day), and to determine the effect of selected clinical and individual variables on cognitive functioning of patients.

The studies were conducted at the Department of Cardiac Surgery, Medical University of Lublin. The study sample consisted of 18 patients (9 women and 9 men) from the 25 pre-qualified for the cardiac surgery of the implantation of coronary artery bypass graft with extracorporeal circulation. Everyone consented to participate in the study. In the second stage 7 people resigned from performing some of the tasks, thus finally the results of 18 patients were analyzed. The age of patients ranged from 55-81 years ( $M = 66.44$ ,  $SD = 6.45$ ), 10 patients (56%) had primary or vocational education, 8 patients (44%) secondary and higher. The group of patients was significantly differentiated in terms of the duration of extracorporeal circulation and aortic clamping time (range 43-244 minutes,  $M = 107.0$ ,  $SD = 45.49$ ). The clamp time was within the range 26-168 minutes ( $M = 64.94$ ,  $SD = 34.14$ ). Beyond the coronary artery disease, the majority of patients had also diagnosed other somatic symptoms: 6 people had previously percutaneous coronary angioplasty (PCI) and in 2 patients perioperative complications occurred. In the EuroSCORE (European System for Cardiac Operative Risk Evaluation ) 60% received 3 or more points (a group of medium/high risk), 40% - less than 3 points (low risk). Somatic state data of the participants are shown in Table 1

Table 1 **Characteristic of the somatic state of patients participating in the study (N=18)**

Disease	N	%
Cardiovascular diseases and other cardiovascular burdens		
Coronary heart disease including:	18	100
3 arteries stenosis over 50 %	14	7
2 arteries stenosis over 50%	2	11
1 artery stenosis over 50%	2	11
Valvular disease	3	16
Previous myocardial infraction	8	44
Hypertension	14	78
Cardiac failure	6	33
Non-cardiovascular diseases		
Diabetes	13	72
Hypercholesterolemia	5	28
Asthma	2	11
Other	7	39

N – sample size

All patients were subject to two-time, individual psychological examinations: the first took place the day before the scheduled operation, and the second in 7<sup>th</sup> or 8<sup>th</sup> day after the surgery. Taking into account the psychosomatic state of the patients, short tasks were selected.

## Method

For neuropsychological assessment of patients, the following tools were used:

The Benton Visual Retention Test. The purpose of the person examined is the most accurate reproduction (copy or from memory) of sequentially shown geometrical figures. The results are a measure of visual-constructional abilities and attention [14]. In the discussed studies a modified version of the test was used, requiring from the studied person recognition of the presented earlier pattern. For 10 seconds (according to method A) each of the 10 patterns of the C version was sequentially shown. Then the examined was supposed to select (recognize) the pattern previously seen within three other patterns (where the other two were from the parallel version of the test, that is D and E). For the correct identification of each pattern 1 point was granted, for incorrect 0 points.

Subtest Similarities of the D. Wechsler Intelligence Quotient - WAIS-R-PL, It consists of 14 tasks: one must provide essential feature common to both concepts or the concept superior of appropriate level of generality. The subtest assesses abstract thinking, identification of objects and concepts, the ability to classify. It also informs indirectly about the language skills and general intelligence [15] The examined for each task can receive 0, 1 or 2 points, in total 0 to 28 raw points, which can then be changed to the converted results [16].

Verbal fluency (K, F, Animals, Supermarket). These tasks measure the ability to provide terms in accordance with a specific semantic (category) and the sound (letter) criterion. They evaluate semantic and operational memory resources and executive functions defined as the ability to plan and use different strategies to recall words [17, 18]. The participants' task was to give as many words from the phonetic (K, F) or semantic (Animals Supermarket) category. Each task lasted for a minute [18]. The number of correctly generated words was taken into account. Polish standards have not been developed for the execution of various fluency tasks yet, but the data indicate that people aged 53.4 years on average, mention nearly 20 units of animals, and at the age of 66 years give an average of 18.3 animals names, 15.7 words on the letter K and 12.6 on F [19].

The Memory Effectiveness Assessment Questionnaire (KEP) by A. R. Giovagnoli et al. (1997) [experimental version, own translation]. It is a method of self-report, which contains 28 questions on various aspects of self-knowledge, i.e., the subjective assessment of own concentration and orientation, knowledge of one's own pre-illness memory, episodic and prospective memory, response to memory difficulties, using mnemotechnics, awareness of memory deficits. Referring to the questions, the examined has a choice of five appropriately scored categories of responses, where "never" equals 5 points, "always" - 1 point. The results range includes 28 points (subjective feeling of impairing memory abilities) to 140 (satisfaction with own mnemonic abilities)

related to absence and/or unnoticeability of own deficits of memory). Because of the psychometric properties (reliability of the original method is 0.87) KEP is used in clinical practice to assess the level of self-awareness, insight into own functioning, there has been no Polish adaptation [20].

The basis for the quantitative analysis was to compare the results obtained in the first (pre-operative) and the second (postoperative) measurement. The impact of sociodemographic (i.e., age, sex, level of education) and clinical (extracorporeal circulation time, aortic clamping time, the absence or presence of the burden in the form of a history of previous myocardial infarction, heart failure, diabetes) variables was taken into consideration. SPSS 17.0 program for Windows was used. For the comparison of the dependent data with the normal distribution the parametric Student's t test for the significance of differences was applied, for the variables deviating from normal distribution - the non-parametric Wilcoxon signed-rank test, for independent data - U Mann-Whitney test, and for correlation analyzes - Spearman's rank  $\rho$  correlation coefficient [21].

## Results

Low mean raw results obtained in WAIS sub-test Similarities in the preoperative measurement suggest significant difficulties of the examined in abstract thinking. These results are also characterized by considerable diversity. The participants obtained almost maximal results in the test of geometrical stimuli recognition (Benton Visual Retention Test). Number of words recalled in the fluency tasks is lower than the mean scores of adults untreated neurologically, psychiatrically or somatically, cited in Polish literature. KEP results suggest that respondents positively evaluate their own memory (see Table 2).

**Table 2. Means, standard deviations and significance of differences between results in tests: before and after cardiosurgical intervention.**

	Measurement I		Measurement II		T/Z (p)	Indicator of improvement M (SD)
	MM	SSD	MM	SSD		
Subtest Similarities	11.11	7.59	12.22	7.65	- 2.51 (0.022*)	1.11 (1.87)
Verbal Fluency letter K	11.89	4.22	12.67	3.85	-1.26 (0.23)	0.78 (2.63)
Verbal Fluency letter F	9.94	3.94	9.44	3.03	0.80 (0.43)	-0.5 (2.8)
Verbal Fluency "Animals"	14.0	3.81	15.89	5.21	-2.65 (0.02*)	1.89 (3.03)
Verbal Fluency "Supermarket"	17.06	4.84	19.78	5.90	-2.70 (0.01**)	2.72 (4.28)
The Memory Effectiveness Assessment Questionnaire	109.39	7.96	112.61	9.40	-1.65 (0.12)	3.22 (8.26)
The Benton Visual Retention Test	9.50	0.85	9.78	0.43	-1.41 (0.16)	0.28 (0.84)

\* $p < 0.05$ ; \*\* $p \leq 0.01$ ; T-value of the Student t-test, Z - value Z of the Wilcoxon test, M - arithmetic mean, SD - standard deviation; - 1 - positive value indicates improvement of results, negative - their reduction after the treatment.

To illustrate the nature of the changes in execution of tasks the improvement indicator (W) was used, being the difference between the results of preoperative and postoperative measurements. A positive result, i.e., higher than 0, indicates improvement in postoperative period, the negative one - deterioration (see Table 2). The sign of the W means, and the means of raw results indicate that in comparison to the results from pre-surgery period, in the postoperative period patients received higher results in most cognitive tasks (Table 2), including significantly in the sub-test Similarities as well as in verbal fluency (Animals Supermarket), which indicates that after the CABG surgery patients coped better with tasks that require abstract thinking, attention and recall of concepts according to semantic criteria. There were no significant differences between the first and second measurement in the recognition of visual stimuli, level of implementation of literal fluency (K) and evaluation of their own memory. Level of performance of literal fluency (F) was non-significantly lower after the operation.

There was no significant correlation between age and the results of the examined in any of the measurements. There were also no significant correlations between the duration of extracorporeal circulation and aortic clamping time and the results of the post-operative phase. Correlations were also not indicated after taking into consideration the improvement coefficient (W).

In the vast majority of cases (I and II measurement) higher mean was obtained in the females group : significant in the recognition of visual material (M:  $9.11 \pm 1.05$  vs. F:  $9.89 \pm 0.33$ ,  $p < 0.05$ ), while in the postoperative phase - in terms of verbal fluency (Supermarket: M:  $16.89 \pm 5.23$  vs. F:  $22, 67 \pm 5.27$ ,  $p < 0.05$ ). In the female group, most of the results were higher in the post-operative examination - significantly in the semantic fluency (Animals:  $14.67 \pm 4.41$  vs.  $17.00 \pm 5.05$ ,  $p < 0.05$ ; Supermarket  $17.33 \pm 5, 54$  vs.  $22.67 \pm 5.27$ ,  $p < 0.01$ ). Men in the postoperative phase scored significantly better results in visual recognition tasks ( $9.11 \pm 1.05$  vs.  $9.89 \pm 0.33$ ,  $p < 0.05$ ) and significantly better assessed their mnemonic abilities ( $109.89 \pm 9.35$  vs.  $114.89 \pm 7.90$ ,  $p < 0.05$ ).

Persons with higher formal education in both measurements performed better than those with lower level of education, however, both groups received higher scores after treatment (Table 3 *next page*). After treatment, in patients with lower education a significant improvement was reported in the of literal fluency ("K":  $8.70 \pm 1.64$  vs.  $10.20 \pm 2.10$ ,  $p < 0.05$ ), while in the group of people with higher education in the semantic fluency (Animals:  $16.13 \pm 4.55$  vs.  $19.25 \pm 5.17$ ,  $p < 0.05$ ; Supermarket:  $20.88 \pm 3.44$  vs.  $24.25 \pm 4.06$ ,  $p < 0.05$ ).

The results of persons who have previously had myocardial infarction do not differ significantly from the results of the patients without this burden, however these persons achieved slightly lower means of results, and their results were characterized by higher changeability than of persons who did not have the heart attack. Patients who had not had heart attack before, after surgery achieved significantly higher score in terms of semantic fluency (Supermarket:  $16.90 \pm 5.28$  vs.  $20.60 \pm 4.19$ ,  $p < 0.01$ ).

Before the surgery, persons with the circulatory insufficiency diagnosed received significantly worse scores in semantic fluency than patients without circulatory insufficiency (Animals:  $15.00 \pm 4.28$  vs.  $12.00 \pm 1.14$ ,  $p < 0.05$ ; Supermarket:  $18.75 \pm 4.41$

Table 3. Level of education: comparison of the patients' results

Task	Primary/ Vocational N=10		Secondary/ Higher N=8		T/Z	Significance level
	M	SD	M	SD		
<b>Measurement I (before surgery)</b>						
Benton Test	9.20	1.03	9.88	0.35	Z=-1.706	0.09
Similarities	5.30	3.37	18.38	4.07	T=-7.465	0.00***
Verbal fluency „K“	8.70	1.64	15.88	2.70	T=-6.988	0.00***
Verbal fluency „F“	7.90	2.68	12.50	3.89	T=-2.967	0.009**
Verbal Fluency „Animals“	12.30	2.06	16.13	4.55	T=-2.205	0.05*
Verbal Fluency „Supermarket“	14.00	3.43	20.88	3.44	T=-4.218	0.01**
Memory Effectiveness Assessment Questionnaire	106.50	6.10	113.00	8.90	T=-1.839	0.085
<b>Measurement II (after surgery)</b>						
Benton Test	9.70	0.48	9.88	0.35	Z=-0.862	0.39
Similarities	6.20	3.05	19.75	3.69	T=-8.538	0.00***
Verbal fluency „K“	10.20	2.10	15.75	3.28	T=-6.616	0.00***
Verbal fluency „F“	7.70	1.89	11.63	2.82	Z=-0.668	0.50
Verbal Fluency „Animals“	13.20	3.52	19.25	5.17	T=-2.950	0.001**
Verbal Fluency „Supermarket“	16.20	4.57	24.25	4.06	T=-3.899	0.001**
Memory Effectiveness Assessment Questionnaire	110.80	10.0	114.88	8.64	T=-0.910	0.38

\*p<0.05; \*\*p<0.01; \*\*\*p=0,00 T-value of the Student's t-test, Z – value Z for the Z Mann-Whitney U test, arithmetic mean, SD – standard deviation, N-sample size

vs.  $13.67 \pm 4.03$ ,  $p < 0.05$ ). After the treatment, there were no significant differences between groups, but higher mean scores in most of the tasks in the two measurements were achieved by persons without circulatory insufficiency. After surgery, they also performed significantly better the task on abstract thinking (Similarities:  $11.67 \pm 6.96$  vs.  $13.25 \pm 6.77$ ,  $p < 0.05$ ) and semantic fluency (Supermarket:  $18.75 \pm 4.41$  vs.  $21.25 \pm 5.99$ ,  $p = 0.05$ ). In people burdened with circulatory insufficiency, there were no significant differences in cognitive functioning before and after surgery, however, the mean scores were slightly higher in the post-operative measurement.

In examination I people with diabetes did not differ significantly in the level of task performance from the non-diabetic patients. In the postoperative phase people with diabetes, surprisingly, performed significantly better in tasks on geometrical stimuli recognition from those without diabetes ( $9.40 \pm 0.55$  vs.  $9.92 \pm 0.28$ ,  $p < 0.05$ ). They also received higher scores in abstract thinking (Similarities:  $10.08 \pm 7.28$  vs.  $11.62 \pm 7.65$ ,  $p < 0.05$ ), verbal fluency (Animals:  $14.15 \pm 3.34$  vs.  $16.54 \pm 5.47$ ,  $p < 0.05$ ), and

they assessed higher their own memory ( $108.77 \pm 7.23$  vs.  $114.54 \pm 7.88$ ,  $p = 0.01$ ). In the group of patients without diabetes no significant difference between the two measurements were found.

### Discussion of results

The aim of this study was to determine the dynamics of selected cognitive functions in patients treated with cardiological surgery (within 7-8 days after the treatment) and to determine some of the factors that can modify the state of a patient in the early postoperative phase. Selective, i.e. concerning certain tasks (evaluating abstract thinking and semantic fluency) significant increase in the post-operative phase was indicated. However, they still fall within the limits of low results [16, 19]. The degree of improvement is not large (e.g. 1-2 points more) and is still varied within the group. These results are not in contradiction with reports of distinct worsening of neuropsychological deficits in the first days after surgery [1], and the results obtained here - seemingly optimistic - may be associated with a modest range of diagnostic techniques used and small sample size. Better results obtained by patients in the postoperative phase are associated with better post-operative blood circulation and the cardiac output [4, 5] or reduction of the impact of significant, but not controlled by us variables (e.g., level of anxiety). CABG is in fact for the patient an event of the nature of psychological crisis [22], so in a large part of those waiting for surgery may occur, of varying degrees, mood disorders, negatively influencing the focus of attention, and thus the on various cognitive functions. The intensification of symptoms of anxiety and depression decreases within a few days after surgery [23, 24, 25]. Therefore, the patients' higher scores in the cognitive tasks in the postoperative phase of treatment may be due to improvement of attention processes, but do not guarantee a fixed/permanent cognitive improvement. On the other hand, no differences in the results of some of the methods of the two phases of treatment may be associated with a small degree of difficulty (e.g., in Benton test it was required to identify, rather than to recall) or with insensitivity of the method for processes affected by CABG (memory self-evaluation techniques). Heterogeneity of the group in terms of clinical parameters and its small size, incline to treat the data with caution.

Contrary to the data indicating that the advanced age may contribute to the occurrence of postoperative neuropsychological deficits [5], our results did not confirm such a link.

We recorded a predominance of women in cognitive functioning in both stages of the study, especially in tasks measuring verbal fluency. This result, although it may be an artefact, is in line with the discussion on the relationship between gender and psychosocial pre-and post-operative functioning. Various gender-related profiles of psychological, medical and functional features of patients treated with CABG were described, indicating greater accumulation/coexistence of unfavorable factors in females in the pre-and postoperative phase (obesity, diabetes, frequent inflammations, advanced age, lower education etc.) [26, 27].

Better educated individuals presented greater opportunities in most cognitive tasks performed in both measurements. This is consistent with the observation that the earlier mental training and greater resources of knowledge play the role of cognitive reserve, thus improving the postoperative functioning [1, 28, 29]. This is a cautious conclusion, as the average results after surgery were higher regardless of the level of education.

Preoperative burdens, i.e., previous myocardial infarction, diabetes and circulatory insufficiency, did not significantly affect cognitive functioning of patients after CABG surgery. It should be noted that selectively (for example, in terms of verbal fluency) higher results were obtained in patients without circulatory insufficiency. People burdened with circulatory insufficiency are at increased risk of cognitive impairment already in the pre-operative phase. In the case of other burdens mentioned, no significant differences were noticed in cognitive functioning at any stage of treatment. It is interesting that in the postoperative phase, persons with diagnosed diabetes, compared to the unburdened ones, obtained higher scores in visual recognition; they were also characterized by better verbal skills in the postoperative measurement in comparison to the results from before the surgery. Diabetes is a source of health complications, which are connected with metabolic disturbances increasing the risk of cerebral complications [5, 30], however patients with controlled, stable blood glucose levels are less vulnerable to neuropsychological disorders [5, 30]. Due to the small number of study participants, these results may be coincidental. There was also no significant correlation between postoperative cognitive functioning of patients and the length of extracorporeal circulation and aortic clamping time, although reports indicate the relationship of these aspects of the surgery with the risk of embolism, and the subsequent deterioration in the functioning of patients [5, 31] explained also by metabolic changes, withdrawing shortly after surgery [32].

Concluding, the combination of clinical and individual factors complicates the assessment of cognitive functioning of patients undergoing CABG surgery, which is one of the causes of heterogeneity of research reports. Studies in larger groups, longitudinal (over a year after surgery), taking into account the greater range of clinical and individual variables [33], and the use of standardized neuropsychological diagnostic tools [34, 35] would make it possible to assess the cognitive processes and their dynamics in the treatment process.

### Conclusions

1. In comparison to the preoperative phase, in the post-operative phase patients treated with cardiovascular surgery achieved significantly better results, but still within the limits of low scores in three out of the seven methods used to assess cognitive functioning, namely in verbal fluency, abstract thinking and the semantic fluency.
2. Factors contributing to improvement of cognitive state in the postoperative phase, are higher formal level of education and lack of circulatory insufficiency burdens.

3. There is a need for long-term assessment of cognitive functioning in people after CABG using a short battery of neuropsychological assessment, taking into account the specificity of cardiosurgical departments, Polish cultural conditions and various psychological and medical parameters.

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Received: 20.10.2011

Reviewed: 03.09.2012

Received after correction: 13.09.2012

Accepted for publication: 13.09.2012

Sub-edited by A. K.

Translated by Katarzyna Cyranka, MA