Psychology in Russia: State of the Art
Volume 10, Issue 2, 2017

Russian Psychological Society
Lomonosov Moscow State University

CLINICAL PSYCHOLOGY

The dynamics of the cognitive functioning and emotional state of cardiac patients during rehabilitation after coronary revascularization

Daria A. Eremina[a,b *], Olga Yu. Shchelkova[a]

[a] *Medical Psychology and Psychophysiology Chair, Saint Petersburg State University, Saint Petersburg, Russia*

[b] *Research Laboratory of Rehabilitation, Federal Almazov North-West Medical Research Centre, Saint Petersburg, Russia*

*Corresponding author. E-mail: daria.a.eremina@gmail.com

Background. Coronary artery bypass grafting (CABG) has been one of the most performed surgical procedures for more than 30 years. Recent research has shown severe cognitive disorders accompanying cardiac surgery. However, mild cognitive dysfunction, which is more amenable to prevention and correction, has been less studied because of difficulties in diagnosing it.

Objective. For this reason, we set out to analyze the dynamics of cognitive functioning in CHD patients undergoing CABG. Our study focuses on the main indicators of cognitive functioning and on comparing cognitive functioning with normative data, as well as on the emotional state which accompanies cardiac surgery.

Methods. The present study enrolled 70 patients (of average age 59.71 ± 7.32 years) who underwent CABG with the standard cardiopulmonary bypass technique. Our examination used a pathopsychological test battery (including the WAIS, TMT, Stroop test, TAS, Benton test, etc.), and was performed in three stages: two days before, and both 12–14 days and three months after the surgery.

Results. The results obtained suggest that the majority of cognitive complaints are connected with memory decline after CABG. Patients with CHD experience significant postoperative cognitive decline mostly in verbal memory and attention. A significant cognitive improvement three months after the operation occurred in the following cognitive domains: visual memory, logical memory, and spatial thinking. An analysis of the patients' trait anxiety leads to the conclusion that the highest intensity of anxiety was observed in relation to the following indicators: "emotional discomfort," "asthenic component," and "anxious assessment of the future."

ISSN 2074-6857 (Print) / ISSN 2307-2202 (Online)

doi: 10.11621/pir.2017.0214
http://psychologyinrussia.com

Conclusion. Our research demonstrates negative changes in both short- and long-term memory. Possible reasons for postoperative cognitive decline include the conditions and consequences of the surgery, normal aging, brain injury at the time of coronary surgery, and the emotional state of the patients. A positive trend was discovered in the visual and logical memory, active attention, and thinking activity.

Keywords: cognitive functions, emotional state, coronary heart disease, rehabilitation, cardiac surgery

Introduction

Approximately 16.7 million people in the world die every year from cardiovascular diseases, including coronary heart disease (CHD). CHD is the leading disease in incidence and mortality in the general population (Leal, Luengo-Fernández, Gray, Petersen, & Rayner, 2006; World Health Statistics 2006). One of the most important treatments for coronary heart disease is myocardial revascularization. It is carried out with the use of either coronary artery bypass surgery (CABG) or transluminal coronary angioplasty balloon. However, coronary bypass surgery has been the most commonly performed surgical procedure for more than 30 years.

Numerous studies have demonstrated the effectiveness of CABG in treating coronary artery disease. At the same time, myocardial revascularization is associated with the risk of both operating and postoperative complications. The hospital postoperative period is often complicated by neurological disorders, postpericardiotomy syndrome, and atrial fibrillation (Eagle et al., 2004). In addition, this group of patients frequently experiences cognitive impairment as a result of the operation. The current level of development of cardiac technology has resulted in a significant reduction in the incidence of severe neurological complications. At the same time, mild postoperative neurological disorders (primarily, cognitive decline) remain a widespread problem (Bergh, Backstrom, Jonsson, Havinder, & Johnsson, 2002). Thus, the frequency of neurocognitive deficits after coronary artery bypass surgery remains high, and, according to some research, it reaches 50-80 % (Van Dijk et al., 2000; Mathew et al., 2003). According to other studies, it varies in the range of 20–79 % (Browne, Halligan, Wade, & Taggart, 2003).

In general, the cognitive impairment means a subjectively and/or objectively detectable reduction of cognitive functions (attention, memory, gnosis, praxis, speech, thought, etc.), which affects the efficiency of learning, professional, consumer, and social activities, as compared with the individual's original state, and also with educational and age norms.

In recent years increased attention has been paid to the problem of the cognitive impairment after myocardial revascularization. The need for this is determined by a number of circumstances. First, the vast majority of previous studies evaluating the effect of CABG on cognitive abilities, considered the long-term effects of the operation (Marasco, Sharwood, & Abramson, 2008; Selnes, 2004). However, studies of cognitive status in the early postoperative period are limited and conflicting. For instance, some studies (Hudetz, Patterson, Byrne, Pagel, & Warltier, 2009) describe a deterioration of cognitive and neurophysiological indicators in the early postoperative period. But several other authors report an absence of changes

(Sweet, 2008) and even an improvement of cognitive functioning (Van den Goor et al., 2008) after CABG.

Second, recent studies have shown significant and persistent cognitive impairment in cardiac patients undergoing surgery. At the same time, mild cognitive dysfunction, not reaching the level of dementia but going beyond the norms (Fonyakin, Geraskina, Magomedov, & Atayan, 2011), remains outside the scope of the research.

Finally, most studies (Derevnina et al., 2013; Fonyakin et al., 2011) only identify the presence of certain cognitive disorders which accompany cardiac pathology. Although, according to recent studies, psychological factors contribute significantly to negative outcomes of coronary surgery (Bokeria, Zinchenko, & Kiseleva, 2013), the psycho-social, emotional, and personality factors of cognitive impairment — in particular, the level of anxiety and alexithymia — remain almost uninvestigated.

Thus, the present research aims to carry out a comprehensive study of the peculiarities and disorders of cognitive functioning in CHD patients undergoing CABG. We also aim to evaluate the emotional factors determining these peculiarities and disorders. Our work focuses on studying the following aspects:

1. The dynamics of the main indicators of the cognitive functioning of CHD patients undergoing CABG, including active attention, the rate of psychomotor reactions, mental capacity, mnestic activity, and verbal-logical and spatial thinking.
2. An analysis of the cognitive functioning of CHD patients (measured before the surgery and at different stages of the rehabilitation process) in comparison with normative data.
3. The dynamics of the state anxiety of CHD patients undergoing CABG before the operation and during rehabilitation.
4. Correlation of the dynamics of cognitive functioning with trait anxiety (measured during the preparation for CABG) and state anxiety (measured before the surgery and at different stages of the rehabilitation process).
5. The level of alexithymia of CHD patients in the period of preparation for surgery.

Method

Characteristics of the experimental group and description of methods. This study involved patients undergoing treatment in a rehabilitation unit of Federal Almazov Medical Research Center (Saint Petersburg, Russia). 70 patients of working age who had undergone CABG were studied. Among them were 58 men (82.9 %) and 12 women (17.1 %); the average age of the patients was 59.71 ± 7.32 years. The testing was performed in three stages: one-two days before CABG, immediately before discharge (12–14 days after CABG), and three months after CABG. Informed consent was obtained from all patients. All patients were medically stable at the point of inclusion in the study.

The methods for studying cognitive functions were selected in line with the bio-psycho-social approach in modern clinical psychology (Wasserman, Trifonova, & Schelkova, 2011), and in accordance with the research purposes and the

"Statement of consensus on assessment of neurobehavioral outcomes after cardiac surgery" (Murkin, Newman, Stump, & Blumenthal, 1995).

For studying cognitive functions (the main characteristics of active attention, rate of psychomotor reactions, mental capacity, mnestic activity, and verbal-logical and spatial thinking) of CHD patients undergoing CABG, the following methods were used:

1) "The Trail Making Test" (TMT) was used to study psychomotor speed, attention switching, and mental flexibility. (Examples of the test are given on the slide.) The patients were asked to draw a line through numbered circles in numerical order as fast as possible, and then by alternating between numbered and lettered circles (1–A–2–B– and so on) (Zotov, 1998);
2) The subtests "Similarities" and "Block Design" from the Wechsler Adult Intelligent Scale (WAIS) were used to study abstract verbal reasoning and spatial thinking (the patients were asked to use hand movements in rearranging blocks with various color patterns on different sides to match a pattern) (Gilyasheva, 1987);
3) A verbal learning test "10 words" was used to study short- and long-term verbal memory. The retained measures were the total number of words immediately recalled, and delayed recall after 50–60 minutes (Bleicher, Crook, & Bokov, 2006);
4) The pathopsychological method "Remembering stories" was used to study logical memory. The patients were asked to retell a short story (Bleicher, Crook, & Bokov, 2006);
5) The pathopsychological sample "Simple analogy" was used to study verbal-logical thinking. An individual was asked to establish a connection between different concepts by analogy with an example (Bleicher, Crook, & Bokov, 2006);
6) "The Benton Visual Retention Test" was used to study visual perception and visual memory. An individual was shown 10 designs. (These designs are shown on the slide.) The patients were asked to reproduce each of the designs on plain paper from memory as precisely as possible (Wasserman et al., 2011);
7) "The Stroop Color-Word Test" was used to study two indicators: processing speed, as well as selective attention and resistance to cognitive interference. This test was conducted only before the surgery and three months after it (Zotov, 1998).

The patients' emotional state in the perioperative period and its dynamics in the rehabilitation process were studied using "The Integrative Anxiety Test (ITT)" (Bizyuk et al., 2005). To investigate the level of alexithymia, we used "The Toronto Alexithymia Scale (TAS)" (Yeresko et al., 1994).

Statistical analysis of study results. The results obtained were processed with the use of the standard statistical techniques included in SPSS 19 and Statistica. We used Wilcoxon signed rank tests for a comparative analysis of the preoperative and postoperative variables of cognitive functioning. The scores obtained versus normative scores were analyzed by using t-tests. Differences were considered significant at $p < 0.05$.

Results

First, in accordance with the research purposes, the dynamics of the main indicators of cognitive functioning of the CHD patients during rehabilitation after CABG were studied (Table 1).

Table 1. Indicators of cognitive functioning of patients undergoing CABG

The main indicators of cognitive functioning	The first stage (before CABG) A	The second stage (12–14 days after CABG) B	The third stage (three months after CABG) C	Significant differences
	M ± m	M ± m	M ± m	
Short-term verbal memory (“10 words”), the number of reproduced words after 5 presentations	7.97 ± 1.58	8.05 ± 1.46	7.24 ± 1.87	AC*** BC**
Long-term verbal memory (“10 words”), the number of reproduced words after 1 hour of presentation	5.44 ± 2.09	5.78 ± 2.05	3.20 ± 1.84	AC*** BC***
Visual memory (Benton test), score	6.64 ± 1.76	7.03 ± 2.05	7.96 ± 1.56	AC* BC**
Logical memory (“Remembering stories”), score	3.98 ± 1.17	4.35 ± 1.06	4.64 ± 0.99	AB** AC* BC**
Verbal-logical thinking (subtest “Similarity”), score	15.72 ± 4.29	17.20 ± 3.88	17.32 ± 3.84	AB**
Verbal-logical thinking (“Simple analogy”), score	7.68 ± 2.13	8.27 ± 1.78	8.04 ± 2.28	AB***
Spatial thinking (subtest “Block Design”), score	29.82 ± 10.47	29.43 ± 11.17	32.0 ± 12.47	AC**
Rate of psychomotor reactions, attention concentration (TMT-A), score	5.18 ± 2.93	5.05 ± 3.33	6.50 ± 3.23	
Attention switching (TMT-B), score	5.17 ± 3.0	4.57 ± 3.41	6.0 ± 3.46	AB*
Processing speed (Stroop-test), score	7.21 ± 2.16		8.29 ± 2.31	
Selective attention (Stroop-test), score	2.97 ± 2.87		5.26 ± 3.67	AC***

Notes. In this and the subsequent tables, the notations *, **, and *** correspond to the statistical significance of $.05 < p < .1$, $p < .05$, and $p < .01$ respectively.

In the TMT and Stroop-test values smaller than 4 points mean that the indicators are less than the normative level (Zotov, 1998).

The results presented in Table 1 show that three months after the operation, the short-term verbal memory span is statistically significantly lower than before CABG. The results also demonstrate the reduction of the short-term verbal memory span in the period from the hospital (second) stage of the study to the third stage. As to the long-term verbal memory span, the same statistically significant trend was also observed. On the contrary, the visual memory indicator increases during post-hospital recovery, and during the whole period of observation (from the first to the third stage). Logical memory improves to a statistically significant extent during both the hospital treatment period (from the first to the second stage of the study) and the entire period of observation (from the first to the third stage of the study). Thus, a reduction in the verbal memory span and improvement in the visual and logical memory as a result of CABG was demonstrated.

The verbal-logical thinking, spatial thinking, and abstract verbal reasoning of the patients were also studied. The indicator of verbal-logical thinking (measured by the subtest “Similarity” and the method “Simple analogy”) was statistically significantly higher 12–14 days after CABG than before the operation. A positive dynamic in spatial thinking was also discovered: Namely, the indicator measured three months after the surgery was statistically significantly higher than the preoperative one. These data suggest that CABG can have a positive impact on the CHD patients’ mental activity.

The patients’ psychomotor speed, attention switching, and mental flexibility were studied by the Trail Making Test. Statistically significant differences in the rate of psychomotor reactions, processing speed, and attention concentration (measured by the TMT and Stroop-test) were not observed. However, the indicator of attention switching (the TMT) was statistically significantly lower after surgery than before. At the same time, three months after the operation, the indicator of selective attention (Stroop-test) was statistically significantly higher than before CABG. This fact indicates an improvement in attention switching and in functioning under the influence of extraneous stimuli, and a reduction in the tendency to be interrupted during mental work.

Table 2. Comparison of cognitive functioning of patients undergoing CABG, with the normative data

The main indicators of cognitive functioning	**The first stage (before CABG) A**	**The second stage (12-14 days after CABG) B**	**The third stage (three months after CABG) C**	**The normative data D**	**Significant differences**
	M ± m	**M ± m**	**M ± m**	**M ± m**	
Rate of psychomotor reactions, attention concentration (TMT-A), score	5.18 ± 2.93	5.05 ± 3.33	6.50 ± 3.23	6.75 ± 2.3	AD*** BD***
Attention switching (TMT-B), score	5.17 ± 3.0	4.57 ± 3.41	6.0 ± 3.46	6.31 ± 2.2	AD*** BD***
Selective attention (Stroop-test), score	2.97 ± 2.87		5.26 ± 3.67	5.21 ± 1.8	AD***

Table 2 provides the results of comparative analysis of the normative data of active attention, rate of psychomotor reactions, and selective attention, with the data obtained in this research (the indicators measured before the surgery, 12–14 days after, and three months after).

The data given in Table 2 indicate that, as compared with the normative data (Zotov, 1998), the following differences were obtained. Before the operation and 12–14 days after it, the rates of psychomotor reactions, attention concentration, and attention switching (the TMT) of patients undergoing CABG were statistically significantly lower than normal. The indicator of selective attention (Stroop-test) measured before CABG was statistically significantly lower than the normative data. However, three months after the operation, the indicators of attention and of the rate of psychomotor reactions were not statistically significantly different from the norm. The data obtained confirm the assumption that CABG, which improves the cerebral blood supply, can positively affect patients' cognitive functioning. Thus, the indicators that were lower than the normative data before the operation (perhaps, by virtue of atherosclerosis) were restored to the normal level 3 months after the surgery.

The data reflecting the general level and intensity of various components of state and trait anxiety of CHD patients undergoing surgery were obtained by using "The Integrative Anxiety Test" (ITT). Table 3 shows the results of a comparative study of the intensity of trait anxiety, measured during the preparation for CABG, and the indicators of state anxiety, measured before the operation, 12–14 days before it, and three months after the operation.

Table 3. Indicators of the trait and state anxiety of patients undergoing CABG

Indicators of anxiety components	**Trait anxiety**	**State anxiety on the first stage (before CABG) A**	**State anxiety on the second stage (12–14 days after CABG) B**	**State anxiety on the third stage (three months after CABG) C**	**Significant differences**
	M ± m	**M ± m**	**M ± m**	**M ± m**	
General indicator	4.32 ± 2.03	3.23 ± 2.04	3.1 ± 1.94	3.76 ± 2.26	BC*
Emotional discomfort	5.29 ± 2.09	2.97 ± 2.21	2.46 ± 1.95	4.04 ± 2.2	AB* BC***
Asthenic component	5.14 ± 2.1	3.88 ± 2.12	5.59 ± 2.28	4.92 ± 2.53	AB***
Phobic component	2.94 ± 2.22	3.57 ± 2.33	2.49 ± 2.12	3.32 ± 2.37	AB*** BC**
Anxious assessment of the future	4.14 ± 2.34	3.9 ± 2.52	3.03 ± 2.3	4.2 ± 2.12	AB*** BC*
Social defensive reactions	3.74 ± 2.54	4.28 ± 2.55	3.78 ± 2.63	3.68 ± 2.7	

Note. In the ITT method the average anxiety level is 4-6 points. A high level of anxiety (7 points and above) corresponds to general psychological discomfort and disharmony with the environment (Bizyuk, A. P. et al., 2005).

According to the data given in Table 3, most of the indicators of state and trait anxiety correspond to a low level of intensity. An analysis of trait anxiety leads to the conclusion that the highest intensity of anxiety, which actually corresponds to the average level, was observed for the following indicators: "emotional discomfort," "asthenic component," and "anxious assessment of the future." The data show that dissatisfaction with a certain life situation (possibly caused by the current illness) decreases. The results obtained also signify that patients preparing for the surgery demonstrate the following characteristics: fatigue, moderately expressed fears projected on the time perspective, general concern for the future based on increased emotional sensitivity, and, frequently, lack of confidence in the positive outcome of the treatment.

A comparative analysis of the state anxiety in the course of all three stages of the study show that three months after the surgery, the general indicator was statistically significantly higher than 12–14 days after it. Presumably, this effect is related to the fact that under the constant supervision in a hospital, patients are less likely to experience anxiety, particularly for their health. The intensity of the "asthenic component" of state anxiety before the surgery is statistically significantly lower than 12–14 days after it; the increase is mainly caused by the severity of the intervention and general physical discomfort. A statistically significant decrease in the intensity of state anxiety after the surgery (from the first stage to the second) is detected for the following indicators: "emotional discomfort," "asthenic component," and "anxious assessment of the future." Such a dynamic is probably related to the fact that patients have already successfully undergone the surgery, and fears about the effects of anaesthesia and even of death, typical for the situation of surgical intervention, have not been realized. However, the same indicators demonstrate a statistically significant increase in the level of anxiety after discharge from a hospital. This trend can probably be explained by patients' lack of adjustment to living outside a hospital, and fears about their life and health situations, which can appear when patients are without medical supervision.

Table 4 presents the results of a correlation analysis of the dynamics of cognitive functioning, and trait and state anxiety. The dynamic was computed as the difference between the values before the operation and three months after it. Thus, this dynamic reflects changes in cognitive functioning over the entire period of treatment and rehabilitation.

As shown in Table 4, the less the component "Social defensive reactions" is expressed in the structure of the patient's trait anxiety, the better the dynamic of short-term verbal memory. More positive and considerable changes in long-term verbal memory during the process of treatment and rehabilitation are observed in patients with a lower level of general and "Social defensive reactions" indicators in the structure of their trait anxiety, and lower levels of intensity of the "Phobic component" prior to the operation. In other words, before the surgery the patient's sense of strange threats, loss of self-confidence, and worthlessness are less expressed. The dynamic of visual memory during the restorative treatment is better when the component "Social defensive reactions" (in the structure of state anxiety, measured thrice, as well as in the structure of trait anxiety), is less expressed. A correlation analysis shows a positive correlation between the dynamics of verbal-logical thinking with "Social defensive reactions" (in the structure of trait anxiety),

Table 4. Correlation between the dynamics of cognitive functioning, and trait and state anxiety

Indicators of anxiety components	Dynamics of short-term verbal memory ("10 words")	Dynamics of long-term verbal memory ("10 words")	Dynamics of visual memory (Benton test)	Dynamics of verbal-logical thinking ("Simple analogy")	Dynamics of rate of psycho-motor reactions (TMT-A)	Dynamics of attention switching (TMT-B)
Trait anxiety						
General indicator		0.480*				
Asthenic component					-0.520**	
Social defensive reactions	0.572**	0.554**	0.754**	0.583**	0.682**	0.433*
State anxiety, measured 1-2 days before the operation						
Phobic component		0.580**				
Social defensive reactions			0.609**		0.653**	
State anxiety, measured 12-14 days after the operation						
Emotional discomfort				–0.487*		
Social defensive reactions			0.452*			

Note 4. In Table 4, the symbol * indicates that the correlation is significant for $p < 0.05$ (two-sided), and the symbol ** that it is significant for $p < 0.01$ (two-sided).

and a negative correlation with "Emotional discomfort" (in the structure of state anxiety 12–14 days after CABG). Such a negative correlation can probably be explained by the fact that dissatisfaction with a certain life situation and emotional tension (the indicator "Emotional discomfort") can stimulate patients to participate in rehabilitation activities more actively, and cope with their own illness. The dynamic of the rate of psychomotor reactions is negatively correlated with the "Asthenic component" in the structure of the patient's trait anxiety, and is positively correlated with the "Social defensive reactions" in the structure of both trait and state anxiety (measured immediately before the surgery).

It should be emphasized that the "Social defensive reactions" component of trait anxiety is statistically significantly correlated with the majority of cognitive functioning indicators observed in Table 4. This means that the worse the dynamic, the more patients are likely to experience anxiety in their social contacts, and to consider their social status as a major source of stress and self-doubt.

In accordance with the purposes of this research, the level of alexithymia was measured by using "The Toronto Alexithymia Scale" (TAS) during the patients' preparation for myocardial revascularization. We treat alexithymia as a complex of cognitive and affective personality traits, which can influence the development and course of psychosomatic diseases. The average indicator of alexithymia for all patients examined was equal to 71.94 points (64 points and less indicate the absence of alexithymia; 72 points and more indicate the presence of alexithymia). The absence of alexithymia was demonstrated by only 18.6 % of patients; 44.3 % of patients demonstrate the presence of alexithymia, whereas in the case of about 27.1 % of patients nothing definitive can be said. This finding indicates that 44.3 % of patients undergoing CABG had difficulties in defining (identifying) and describing their own feelings and in distinguishing feelings from body sensations. Also the latter patients have a reduced ability for symbolization (this reduction is evidenced by the poverty of imagination), and are more focused on external events than internal experiences. Such personality characteristics can lead to an amplification of physiological responses to stress, to a fixation on a somatic component of emotional excitement, and to further formation of hypochondriacal positions and psychosomatic disorders.

Discussion

The impact of CABG on cognitive functioning remains a major source of concern among clinicians. Postoperative cognitive decline is of importance because it can have a negative impact on patients' ability to work. According to previous research findings (Pinna Pintor et al., 1992; McCrone et al., 2001), only 40-60 % of patients returned to their work without a reduction in the level of their working capacity and preoperative qualifications. Moreover, postoperative cognitive impairments can result in a decrease in patients' quality of life (Sotaniemi et al., 2001).

Our present research reveals significant and stable changes in cognitive functioning of CHD patients undergoing CABG with cardiopulmonary bypass. In agreement with previous results (Vingerhoets, Van Nooten, Vermassen, De Soete, & Jannes, 1997; Newman, 1993), we observed that patients with CHD experienced significant cognitive deficits three months after the surgery mostly in the memory domain. These results also correspond to those of a variety of studies reporting subjective cognitive complaints, primarily an increase in memory complaints after heart surgeries (Berghet al., 2002; McKhann et al., 2008; Selnes et al., 2004). Thus, short- and long-term verbal memories are more likely to be affected after the surgery than other cognitive functions.

Some researchers (Vingerhoets et al., 1997) consider cerebral embolization and poor cerebral perfusion the most important agents of this damage. Other authors believe that cognitive dysfunction after CABG is related to microembolization from the heart–lung machine, to prolonged hypoperfusion during CABG or anesthesia, to genetic factors (Jensen, Rasmussen, & Steinbrüchel, 2008), and/or to manipulation of the aorta during cannulation and clamping (Vedin et al., 2006). It should also be taken into account that, in contrast to previous studies (Newman et al., 2001; Vingerhoets et al., 1997; Newman, 1993), no significant decline in both short- and long-term verbal memory was observed immediately after CABG. These results suggest that memory decline is not directly related to the conditions and consequences of the surgery. One of the reasons for memory decline immediately after CABG is the patient's asthenic state, which accompanies the rehabilitation process after cardiac surgery (Eremina, 2013).

Moreover, in contrast to several previous studies (Newman et al., 2001; Tonera, Taylor, Newman, & Smith, 2008), we found no significant deterioration in attention switching, or in concentration and psychomotor speed, at the time of discharge from the hospital. This can be explained by the fact that the postoperative cognitive variables were measured a week after CABG in Newman et al. (2001) and Tonera et al. (2008), but two weeks after CABG in our study (as a result of different durations of hospital stay after CABG).

At the same time, we found a significant improvement in abstract verbal reasoning and verbal-logical thinking two weeks after CABG. A significant cognitive improvement three months after the operation occurred in the following cognitive variables: visual memory, logical memory, and spatial thinking. This positive dynamic can result from the coronary revascularisation and improved cerebral blood flow. Another possible reason for this dynamic is correction and prevention of risk factors (included in the rehabilitation program after CABG), which can lead to an improvement in cognitive functioning.

The results of our comparative analysis agree with the previous study (Jensen et al., 2008) which showed that, before surgery and 12-14 days after it, the psychomotor speed, attention switching and mental flexibility, as well as selective attention and resistance to cognitive interference of CHD patients, are significantly lower than normal. However, three months after the surgery, the indicators which were lowered before the operation (possibly in consequence of atherosclerosis) improve to the normal level, which agrees with the known results (Knippa et al., 2004). This dynamic is possibly due to the fact that preoperative cognitive variables of surgery candidates are frequently affected by anxiety or depression (Eremina, 2013). This dynamic can also be related to the coronary artery disease itself, some cerebral complications (Marasco et al., 2008), or a specific psychological state accompanying preparation for the surgery. The data obtained confirm the conjecture that CABG, which improves the cerebral blood supply, can positively affect cognitive functioning of patients.

The results from studying the correlation between cognitive functioning and the level of trait and state anxiety showed that the changes in cognitive functioning are statistically significantly correlated with the indicators of emotional state of the patients. Nevertheless, further investigations of the pathopsychological and physiological mechanisms leading to changes in patients' cognitive functioning, are needed.

The present study has several limitations. One is the restricted number of patients studied. In addition, the preoperative level of cognitive functioning of the patients is considered to have been at a basic level, although the preoperative indicators can be distorted, for instance, by the psychological state of patients. Moreover, the follow-up examination mostly involved compliant patients.

Conclusion

The results obtained in this present research open new ways of optimizing the rehabilitation process and setting new psychotherapy goals for patients undergoing

CABG and other cardiac surgeries. The results described in this paper also can contribute to diagnosing changes in the intellectual activity caused by the disease and vascular cognitive impairments in a timely fashion, and to distinguishing them from age-related changes. Our results emphasize the importance of taking into account peri- and postoperative cognitive changes accompanying cardiac surgery in order to prevent long-term cognitive dysfunction, and permit the patient undergoing cardiac surgery to regain the preoperative level of working capacity and qualification.

References

Bergh, C., Backstrom, M., Jonsson, H., Havinder, L., & Johnsson, P. (2002). In the eye of both patient and spouse: memory is poor 1 to 2 years after coronary bypass and angioplasty. *The Annals of Thoracic Surgery*, *74*, 689–693. doi: 10.1016/S0003-4975(02)03723-2.

Bizyuk, A.P., Wasserman, L.I., & Iovlev, B. (2001). *Primenenie integrativnogo testa trevozhnosti. Metodicheskie rekomendacii* [Application of integrative anxiety test (ITT): methodological recommendations]. Saint Petersburg, Russia: Bekhterev Saint Petersburg Psychoneurological Research Institute.

Bleicher, V.M., Kruk, I.V., & Bokov, S.N. (2006). *Klinicheskaja patopsihologija: Rukovodstvo dlja vrachej i medicinskih psihologov* [Clinical pathopsychology: a guide for physicians and clinical psychologists]. (2nd ed.) Moscow: Moscow Psychological and Social Institute.

Bokeria L.A., Golukhova, E.Z., Shigaev, I.Y., & Keren, M.A. (2012). Sovremennye podhody k hirurgicheskomu lecheniju ishemicheskoj bolezni serdca u bolnyh saharnym diabetom [State-of-the-art approaches to surgical treatment of ischemic heart disease in patients with diabetes mellitus]. *Vestnik Rossijskoj akademii medicinskih nauk* [*Annals of the Russian Academy of Medical Sciences]*, *1*, 20–26. doi: 10.15690/vramn.v67i1.105

Bokeria, L. A., Zinchenko, Y. P., & Kiseleva, M. G. (2013). Psychological factors and outcomes of coronary surgery. *Psychology in Russia: State of the Art*, 6(4), 160–167. doi: 10.11621/pir.2013.0414

Browne, S.M., Halligan, P.W., Wade, D.T., & Taggart, D.P. (2003). Postoperative hypoxia is a contributory factor to cognitive impairment after cardiac surgery. *The Journal of Thoracic and Cardiovascular Surgery*, *126*(4), 1061–1064. doi: 10.1016/S0022-5223(03)00616-0

Derevnina, E.S., Akimova, N.S., Martynovich, T.V., Makarov, N.S., Konshina, L.E., & Schwarz, Yu.G. (2013). Kognitivnye narushenija pri fibrilljacii predserdij na fone serdechno-sosudistyh zabolevanij [Cognitive impairment in atrial fibrillation on a background of cardiovascular disease]. *Annaly aritmologii [Annals of Arrhythmology]*, *10*(2), 87–94. doi:10.15275/annaritmol.2013.2.4.

Eagle, K.A., Guyton, R.A., Davidoff, R., Edwards, F.H., Ewy, G.A., Gardner, … Orszulak, T.A. (2004). ACC/AHA 2004 guideline update for coronary artery bypass graft surgery: summary article: A report of the American College of Cardiology. American Heart Association Task Force on Practice Guidelines (Committee to Update the 1999 Guidelines on Coronary Artery Bypass Graft Surgery). *Circulation*, *110*, 1168–1176. doi: 10.1161/01.CIR.0000138790.14877.7D

Eremina, D. (2013). Osobennosti astenicheskih sostojanij pacientov s ishemicheskoj boleznju serdca posle revaskuljarizacii miokarda [Specific features of asthenic conditions of patients with coronary artery disease after myocardial revascularization]. *Vestnik Juzhno-Uralskogo gosudarstvennogo universiteta. Serija: Psihologija [Bulletin of South Ural State University. Series "Psychology"],* *6*(4), 122–130.

Fonyakin, A.V., Geraskina, L.A., Magomedov, A.R., & Atayan A. (2011). Serdechno-sosudistye zabolevanija i narushenie kognitivnyh funkcij. Profilaktika i lechenie [Cardiovascular disease and cognitive impairment. Prevention and treatment]. *Russkij medicinskij zhurnal [Russian Medical Journal], 19*(403), 538–544.

Gilyasheva, I.N. (1987). *Prakticheskoe ispolzovanie adaptirovannogo testa intellekta v klinike nervno-psihicheskih zabolevanij: Metod. Rekomendacii* [Practical use of the adapted intelligence test at the clinic of neuropsychiatric disorders: guidelines]. Saint Petersburg, Russia: Bekhterev Saint Petersburg Psychoneurological Research Institute.

Hudetz, J.A., Patterson, K.M., Byrne, A.J., Pagel, P.S., & Warltier, D.C. (2009). Postoperative delirium is associated with postoperative cognitive dysfunction at one week after cardiac surgery with cardiopulmonary bypass. *Psychological Reports*, *105*, 921–932. doi: 10.2466/PR0.105.3.921-932

Jensen, B.Ø., Rasmussen, L.S., & Steinbrüchel, D.A. (2008). Cognitive outcomes in elderly high-risk patients 1 year after off-pump versus on-pump coronary artery bypass grafting. A randomized trial. *European Journal Cardio-Thoracic Surgery, 34*(5), 1016–1021. doi: 10.1016/j.ejcts.2008.07.053

Knippa, S., Matatko, N., Wilhelm, H., Schlamann, M., Massoudy, P., Forsting, M., … & Jakob, H. (2004). Evaluation of brain injury after coronary artery bypass grafting. A prospective study using neuropsychological assessment and diffusion-weighted magnetic resonance imaging. *European Journal Cardio-Thoracic Surgery, 25,* 791–800. doi: 10.1016/j.ejcts.2004.02.012

Leal, J., Luengo-Fernández, R., Gray, A., Petersen, S., & Rayner, M. (2006). Economic burden of cardiovascular diseases in the enlarged European Union. *European Heart Journal*, *27*, 1610–1619. doi: 10.1093/eurheartj/ehi733

Marasco, S.F., Sharwood, L.N., & Abramson, M.J. (2008). No improvement in neurocognitive outcomes after off-pump versus on-pump coronary revascularisation: A meta-analysis. *European Journal Cardio-Thoracic Surgery*, *33*, 961–970. doi: 10.1016/j.ejcts.2008.03.022

Mathew, J.P., Grocott, H.P., Phillips-Bute, B., Stafford-Smith, M., Laskowitz, D.T., Rossignol, D., & Newman, M.F. (2003). Lower endotoxin immunity predicts increased cognitive dysfunction in elderly patients after cardiac surgery. *Stroke*, *34*, 508–513. doi: 10.1161/01.STR.0000053844.09493.58

McKhann, G.M., Selnes, O.A., Grega, M.A., Bailey, M.M., Pham, L.D., Baumgartner, W.A., & Zeger, S.L. (2009). Subjective memory symptoms in surgical and nonsurgical coronary artery patients: 6-year follow-up. *The Annals of Thoracic Surgery, 87,* 27–34. doi: 10.1016/j.athoracsur.2008.09.023.

Murkin, J.M., Newman, S.P., Stump, D.A., & Blumenthal, J.A. (1995). Statement of consensus on assessment of neurobehavioral outcomes after cardiac surgery. *The Annals of Thoracic Surgery, 59,* 1289–1295. doi: 10.1016/0003-4975(95)00106-U

Newman, M.F., Kirchner, J.L., Phillips-Bute, B., Gaver, V., Grocott, H., Jones, R.H. … & Blumenthal, J.A. (2001). Longitudinal assessment of neurocognitive function after coronary artery bypass surgery. *The New England Journal of Medicine, 344*(6), 395–402. doi:10.1056/NEJM200102083440601

Newman, S. (1993). Neuropsychological and psychological changes. In P. Smith & K. Taylor (Eds.), *Cardiac surgery and the brain.* (pp. 34–54). London: Hodder and Stoughton.

Pinna Pintor, P., Torta, R., Bartolozzi, S., Borio, R., Caruzzo, E., Cicolin, A., & Ravizza, L. (1992). Clinical outcome and emotional-behavioral status after bypass graft surgery. *Quality of Life Research, 1*(3), 177–185. doi: 10.1007/BF00635617

Sotaniemi, K.A. (1995). Long-term neurologic outcome after cardiac operations. *The Annals of Thoracic Surgery, 59,* 1336–1339. doi: 10.1016/0003-4975(95)00095-3

Selnes, O.A., Grega, M.A., Borowicz, L.M. Jr., Barry, S., Zeger, S., Baumgartner, W. A., & McKhann, G.M. (2005). Cognitive outcomes three years after coronary artery bypass surgery: A comparison of on-pump coronary artery bypass graft surgery and nonsurgical controls. *The Annals of Thoracic Surgery*, *79*, 1201–1209. doi: 10.1097/01.wnn.0000126982.53726.67

Sweet, J.J., Finnin, E., Wolfe, P.L., Beaumont, J.L., Hahn, E., Marymont, J., & Rosengart, T.K. (2008). Absence of cognitive decline one year after coronary bypass surgery: Comparison to nonsurgical and healthy controls. *The Annals of Thoracic Surgery, 85,* 1571–1578. doi: 10.1016/j.athoracsur.2008.01.090

Tonera, I., Taylor, K.M., Newman, S., & Smith, P.L.C. (1998). Cerebral functional changes following cardiac surgery: Neuropsychological and EEG assessment. *European Journal Cardio-Thoracic Surgery, 13*(1)*,* 13–20. doi: 10.1016/S1010-7940(97)00300-X

Van den Goor, J., Saxby, B., Tijssen, J., Wesnes, K., de Mol, B., & Nieuwland, R. (2008). Improvement of cognitive test performance in patients undergoing primary CABG and other CPB-assisted cardiac procedures. *Perfusion, 23,* 267–273. doi: 10.1177/0267659109104561

Van Dijk, D., Keizer, A.M.A., Diephuis, J.C., Durand, C., Vos, L.J., & Hijman R. (2000). Neurocognitive dysfunction after coronary artery bypass surgery (a systematic review). *The Journal of Thoracic and Cardiovascular Surgery*, *120,* 632–639. doi: 10.1067/mtc.2000.108901

Vedin, J., Nyman, H., Ericsson, A., Hylander, S., & Vaage, J. (2006). Cognitive function after on or off pump coronary artery bypass grafting. *European Journal Cardio-Thoracic Surgery, 30*(2), 305–310. doi: 10.1016/j.ejcts.2006.03.037

Vingerhoets, G., Van Nooten, G., Vermassen, F., De Soete, G., & Jannes, C. (1997). Short-term and long-term neuropsychological consequences of cardiac surgery with extracorporeal circulation. *European Journal Cardio-Thoracic Surgery, 11,* 424–431. doi: 10.1016/S1010-7940(96)01031-7

Wasserman L.I., Trifonova E.A., & Schelkova O.Yu. (2011). *Psihologicheskaja diagnostika i korrekcija v somaticheskoj klinike: nauchno-prakticheskoe rukovodstvo* [Psychological diagnostics and correction in somatic clinic: Scientific and practical guided]. Saint Petersburg, Russia: Rech.

World Health Organization (2006). *World Health Statistics*. Geneva.

Zotov, M.V. (1998). *Kognitivnye narushenija i vozmozhnosti ih kompensacii u bol'nyh shizofreniej s razlichnoj stepen'ju vyrazhennosti defekta* [Cognitive impairment and the possibility of their compensation in schizophrenic patients with varying degrees of severity of the defect]. (PhD thesis). Saint Petersburg State University: Saint Petersburg, Russia.

Original manuscript received May 07, 2016
Revised manuscript accepted August 02, 2016
First published online June 30, 2017