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Neuropsychological changes after off-pump and on-pump coronary artery bypass surgery

Alicja Michalak[1], Bożena Szyguła-Jurkiewicz[2], Mateusz Mościński[3], Piotr Muzyk[3], Konrad Samborski[3], Bogumiła Kłaczek[4], Piotr Knapik[4], Marian Zembala[5], Lech Poloński[2]

[1]Psychology Unit, Faculty of Health Science, Medical University of Silesia, Katowice, Poland
[2]3rd Department of Cardiology, Medical University of Silesia, Silesian Center for Heart Diseases, Zabrze, Poland
[3]Student's Scientific Group by 3rd Department of Cardiology, Medical University of Silesia, Katowice, Poland
[4]Department of Cardiac Anaesthesia and Intensive Care, Medical University of Silesia, Silesian Center for Heart Diseases, Zabrze, Poland
[5]Department of Cardiac Surgery and Transplantation, Medical University of Silesia, Silesian Center for Heart Diseases, Zabrze, Poland

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Abstract

Background: A major problem in patients after cardiac surgery are cognitive decline.

Aim of the study: 1. To determine cognitive functions in patients undergoing surgical myocardial revascularisation with extracorporeal circulation (CABG), and without (OPCAB).

2. To determine factors affecting cognitive functions in early postoperative period in analysed group of patients.

Material and methods: The analysis encompassed 160 consecutive patients undergoing elective surgical myocardial revascularisation in 2010-2011. Neuropsychological assessment was carried out one day before and five days after surgery using: Hospital Anxiety and Depression Scale (HADS), Rey Auditory Verbal Learning Test (AVLT), Benton Visual Retention Test (BVRT), Verbal Fluency Test FAS (Controlled Word Association Test), Trail Making Test (TMT), Digit Span Subtest, and Digit Symbol Test – Wechsler Adult Intelligence Scale (WAIS-R PL).

Results: One hundred three of 160 patients, of whom 64 (62.1%) underwent CABG and 39 (37.9%) OPCAB, were qualified for the analysis. After surgery there was a significant decrease in results of Rey Auditory Verbal Learning Test (AVLT), Verbal Fluency Test (FAS), Digit Span Subtest and Digit Symbol Test in the group CABG and in results of AVLT after 30 minuts in group OPCAB. Multi-factor analysis revealed that an unstable disease course caused a decline in verbal skills, whilst surgery with extracorporeal circulation and carotid atherosclerosis had a negative, independent effect on visuomotor coordination and visuospatial operating memory.

Conclusions: 1. In the group CABG cognitive decline regarded top-down attention, echoic memory, sensory procedural memory, recognition and immediate recall verbal symbols, verbal fluency, echoic and iconic learning ability, visual-mo-

Streszczenie

Wprowadzenie: Istotnym problemem u chorych po zabiegach kardiochirurgicznych są zaburzenia poznawcze.

Cel pracy: 1. Porównanie sprawności funkcji poznawczych u chorych poddanych chirurgicznej rewaskularyzacji mięśnia sercowego w krążeniu pozaustrojowym (*coronary artery bypass grafting* – CABG) i bez krążenia pozaustrojowego (*off-pump coronary artery bypass grafting* – OPCAB).

2. Wyznaczenie czynników wpływających na funkcje poznawcze we wczesnym okresie pooperacyjnym

Materiał i metody: Analizą objęto 160 kolejnych chorych poddanych planowemu zabiegowi pomostowania naczyń wieńcowych w latach 2010–2011. Badanie neuropsychologiczne przeprowadzano przed zabiegiem i w 5. dobie po zabiegu, stosując: Szpitalną skalę lęku i depresji, Test uczenia się 15 słów Reya, Test pamięci figur Bentona, Test fluencji słownej FAS, Test łączenia punktów A i B, Test powtarzania cyfr oraz Test symboli cyfr.

Wyniki: Do analizy zakwalifikowano 103 spośród 160 chorych; 64 (62,1%) spośród nich poddano następnie zabiegowi CABG, a 39 (37,9%) zabiegowi OPCAB. Analiza wieloczynnikowa wykazała, że niestabilny przebieg choroby przed zabiegiem powodował pogorszenie sprawności werbalnej, a wykonanie zabiegu z zastosowaniem krążenia pozaustrojowego oraz miażdżyca tętnic szyjnych miały niekorzystny wpływ na koordynację wzrokowo-ruchową i wzrokowo-przestrzenną pamięć operacyjną.

Wnioski: U chorych w grupie CABG stwierdzono pogorszenie uwagi dowolnej, kategorialnej pamięci słuchowej, pamięci operacyjnej wzrokowo-słuchowej, rozpoznawania i aktywnego odtwarzania materiału słownego, uczenia się materiału wzrokowego i słuchowego, sprawności werbalnej, koordynacji wzrokowo-ruchowej oraz tempa przetwarzanych informacji, a u chorych w gru-

Address for correspondence: Bożena Szyguła-Jurkiewicz, MD, PhD, 3rd Department of Cardiology, Medical University of Silesia, Curie-Sklodowskiej 9, 41-800 Zabrze, Poland, email: centrala4@wp.pl

tor coordination and the pace of information processing. In the group OPCAB cognitive decline was observed only with regard to delayed verbal memory, whilst visual memory improved.
2.The independent factors for cognitive decline are: unstable disease course (which lowers verbal fluency), surgery carried out with the classic method using extracorporeal circulation, and carotid atherosclerosis (which has a negative impact on visual-motor coordination and visuospatial operating memory).
Key words: coronary artery bypass grafting, cognitive functions.

pie OPCAB pogorszenie pamięci werbalnej odroczonej.
Niezależnym czynnikiem ryzyka pogorszenia sprawności poznawczych po zabiegu jest niestabilny przebieg choroby wieńcowej przy przyjęciu do szpitala (który pogarsza sprawność werbalną). Niezależnym czynnikiem ryzyka osłabienia wzrokowo-przestrzennej pamięci operacyjnej oraz koordynacji wzrokowo-ruchowej są miażdżyca tętnic szyjnych i zastosowanie krążenia pozaustrojowego.
Słowa kluczowe: pomostowanie naczyń wieńcowych, funkcje poznawcze.

Introduction

Despite the considerable clinical, social and economic advances in surgical techniques, anaesthesiology, perfusion methods and postoperative care, cognitive decline still remains a major complication after myocardial revascularization [1]. The most frequent impairments concern memory, attention, speech, spatial orientation, learning and thinking. Cognitive decline prolongs the recovery time, has a negative impact on social and family interactions, and may even lead to job resignation. It is also a significant risk factor for future cognitive decline. By performing neuropsychological assessment of individual cognitive functions, avoiding factors that may impair cognitive processes, and by introducing early therapy, the incidence of these complications may be lowered and their severity diminished in patients undergoing cardiac surgery. Although the pathology affects a large percentage of patients, only a few centres conduct pre- and post-surgical neuropsychological assessment. This is probably due to the fact that the implementation of precise test batteries is time-consuming and their interpretation requires the participation of a psychologist or a psychiatrist. The available data regarding the incidence and severity of post-operative changes in cognitive functions as well as the factors that negatively affect cognitive functions differ significantly [2-8].

Aim of the study

1. To compare cognitive functions in patients undergoing elective surgical myocardial revascularization with extracorporeal circulation (CABG), or without it (OPCAB).
2. To determine the type of cognitive impairment and the independent factors affecting cognitive functions in the early postoperative period in the analysed groups.

Material and methods

Patients

The prospective analysis encompassed consecutive patients undergoing elective surgical myocardial revascularization between September 2010 and January 2011, with extracorporeal circulation (CABG) or without it (OPCAB), and who gave informed consent to participate in the study. The exclusion criteria were: age > 65 years, neurological and psychiatric diseases, psychotropic drugs used 24 hours before neuropsychological tests, renal failure, liver cirrhosis, respiratory failure, urgent or prior cardiac surgery, simultaneous valve replacement or valvuloplasty, myocardial infarction in the previous 6 weeks, and neoplastic disease. The study protocol was approved by the Bioethics Committee of the Medical University of Silesia (decision no. KNW/0022/KB1/119/10). The study was also completed according to the Code of Professional Ethics for the Psychologist, including standards established in the Helsinki Declaration.

Methods

Before inclusion in the study, the patients' mental state was assessed by means of a structured clinical interview using the General Health Questionnaire (GHQ-12), Mini Mental State Examination (MMSE) and Beck Depression Inventory (BDI-II) [9]. Patients who scored ≥ 14 on the BDI were referred for psychiatric evaluation with a suspected diagnosis of depression. Included in the study were patients who scored < 3 points on the GHQ-12 test [10], > 27 points on the MMSE test [11], and patients in whom no depression was diagnosed based on the ICD-10 criteria [12]. Two equivalent functional neuropsychological assessments were carried out in patients who qualified for the study: one day before surgery (during a routine procedure for hospital admission) and on the 5th postoperative day – shortly before hospital discharge (on both occasions, all patients' mental and physical condition fully permitted the performance of the study). The assessment was conducted by a psychologist. It included the Hospital Anxiety and Depression Scale (HADS), Rey Auditory Verbal Learning Test (AVLT), Benton Visual Retention Test (BVRT), FAS Verbal Fluency Test (Controlled Oral Word Association – COWA), Trail Making Test (TMT), Digit Span Subtest, and Digit Symbol Test. To prevent the learning phenomenon, preoperatively, the A version of the AVLT test and the C version of the BVRT test were used, whilst postoperatively, the B version of the AVLT test and the D version of the BVRT test were used. Test assessment was double-blind, anonymous, with patient data and the surgical technique kept blinded. For 24 h before the neuropsychological tests, the patients did not receive any drugs affecting their cognitive function.

Two different surgical techniques were used: coronary artery bypass graft (CABG) and off-pump coronary artery bypass (OPCAB). The choice of surgical technique lay with the operator.

CABG was carried out under general anaesthesia, via a median sternotomy. The internal thoracic artery and/or the great saphenous vein and/or the radial artery were harvested. After systemic heparinization with 3 mg/kg body weight and obtaining ACT > 480 s, typical cannulisation of the ascending aorta and the right atrium was carried out. Next, extracorporeal circulation began at moderate hypothermia. After clamping the ascending aorta, a cold cardioplegic blood solution was administered into the aortic bulb and/or coronary sinus (10 ml/kg body mass, 4 : 1 ratio). A 300 ml dose of cardioplegic blood was administered every 20 minutes. Next, on a motionless heart, an end-to-side distal coronary anastomosis was performed. After removing the ascending aortic clamp, proximal anastomoses were performed with a side-biting vascular clamp. The extracorporeal circulation was terminated when the patient attained a body temperature of 37°C. In order to reverse the effect of heparin, 3.0 mg/kg body mass of protamine sulfate were administered after the termination of circulation. The median sternotomy was closed in the standard way, with vacuum-assisted drainage.

OPCAB was carried out under general anaesthesia via median sternotomy. Next, the internal thoracic artery and/or the great saphenous vein and/or the radial artery were harvested. After systemic heparinization with 2 mg/kg body mass and obtaining ACT > 380 s, end-to-side distal coronary anastomoses were performed with tissue stabilizers, and in the case of inferior or lateral wall anastomosis, with an apex of the heart stabilizer. In order to ensure the correct positioning of the heart, a 2-0 Prolene deep pericardial suture with seton was used. Two types of stabilizers were used: OCTOPUS II and III by Medtronic (Minneapolis, MN, USA) and Access Device by Guidant (Indianapolis, IN, USA), depending on equipment availability. Intravascular bypasses were routinely used in order to ensure coronary flow during distal anastomosis. Aortic proximal anastomoses were carried out with a side-biting clamp; composite anastomosis was performed with the aortic no-touch technique. In order to reverse the effect of heparin, 1.0 mg/kg body mass of protamine sulfate was administered. The median sternotomy was closed in the standard way, with vacuum-assisted drainage.

Statistical analysis

Data on the interval scale are presented as mean ± standard deviation or median and the upper and lower quartiles. Qualitative data are presented as percentages. The normality of distribution of the obtained results was assessed with the Kolmogorov-Smirnov test. The statistical analysis made use of Student's t-test or Mann-Whitney U-test, χ^2 test or Fisher's exact test and variance analysis with repetition and contrast analysis. In order to assess the effect of clinical variables on changes in psychological tests during follow-up, multiple regression with the backward stepwise procedure was used. Parameters with significance level < 0.05 were considered statistically significant. All calculations were made with the Statistica 8.0 software.

Results

The study encompassed 160 consecutive patients hospitalized at the Silesian Centre for Heart Diseases in Zabrze, who underwent elective surgical myocardial revascularization with CABG or OPCAB between September 2010 and January 2011. After considering the inclusion and exclusion criteria, the final analysis encompassed 103 patients. Out of the 57 patients who were not included in the study, seven scored < 27 points on the MMSE test, 38 were diagnosed with depression based on the ICD-10 criteria, and 10 had a history of cerebral stroke. Fifty-one of the excluded patients were older than 65 and did not comply with the age criterion. Two patients (2%) died during the in-hospital period. Out of the 103 patients who qualified for the study, 64 (62.1%) underwent CABG, and 39 (37.9%) OPCAB. There were no significant differences between the two groups with regard to gender, age, education level or employment status (Table I).

Basic patient clinical characteristics in the two studied groups are presented in Table I. Intra- and post-operative parameters and complications are presented in Table II.

There were more multiple (3-4) grafts among patients undergoing CABG than among patients undergoing OPCAB

Tab. I. Basic patient characteristics in both study groups

	CABG (*n* = 64)	OPCAB (*n* = 39)	*p*
Age (years)	59.7 ±7.7	58.6 ±8.0	NS
Women *n* (%)	16 (15.6%)	21 (20.5%)	NS
Education:			
primary	30 (46.9%)	24 (61.5%)	NS
vocational	5 (7.8%)	0 (0.0%)	NS
secondary	22 (34.4%)	9 (23.1%)	NS
higher	7 (10.9%)	6 (15.4%)	NS
Employment status:			
work	14 (21.8%)	8 (20.5%)	NS
retirement pension	25 (39.1%)	14 (35.9%)	NS
disability pension	25 (39.1%)	17 (43.6%)	NS
EURO score (points)	3.0 (1.0/4.0)	2.0 (1.0/4.0)	NS
Unstable course of disease* *n* (%)	25 (39.7%)	8 (20.5%)	< 0.05
Obesity (BMI > 30) *n* (%)	26 (40.6%)	12 (30.8%)	NS
BMI [kg/m^2]	33.2 ±3.5	31.5 ±1.7	NS
Current tobacco smoking *n* (%)	9 (16.4%)	3 (8.3%)	NS
Intermittent claudication (distance 100-200 m)	7 (10.9%)	3 (7.9%)	NS
LVEF (%)	50.9 ±9.7	49.8 ±8.6	NS
Diabetes *n* (%)	25 (39.1%)	8 (20.5%)	< 0.05
Hypercholesterolaemia *n* (%)	34 (54.8%	20 (51.3%)	NS
Arterial hypertension *n* (%)	50 (78.1%)	29 (74.4%)	NS
CHF symptoms in the past *n* (%)	3 (4.7%)	1 (2.6%)	NS
Past infarction *n* (%)	34 (53.1%)	23 (59.0%)	NS
Past PCI *n* (%)	15 (23.4%)	19 (48.7%)	< 0.01

**change by at least one CCS class upward in the previous two months*
p – level of statistical significance

Tab. II. Intra- and post-operative parameters and complications

	CABG (n = 64)	OPCAB (n = 39)	p
Intraoperative parameters			
Complete revascularization	43 (67.2%)	17 (43.6%)	< 0.05
Duration of surgery (min)	314.4 ±55.8	260.4 ±54.6	< 0.05
Extracorporeal circulation (min)	106.1 ±40.1	–	–
Extracorporeal circulation >120 min	12 (18.8%)	–	–
Postoperative parameters and complications			
Significant inotropic support*	1 (17.2%)	5 (12.8%)	NS
IABP	3 (4.7%)	1 (2.6%)	NS
Mechanical ventilation (hours)	3 (4.7%)	9.1 (6.2/11.5)	NS
Mechanical ventilation >12 h	17 (26.9%)	7 (17.9%)	NS
Mediastinal drainage (ml)	1090.7 ±893.4	736.3 ±376.3	NS
Mediastinal drainage > 1000 ml	5 (7.8%)	3 (7.6%)	NS
Intraoperative infarction	1 (1.6%)	2 (5.1%)	NS
Reoperation due to bleeding	3 (4.7%)	1 (2.6%)	NS
Death	1 (1.6%)	1 (2.6%)	NS

**above-normal doses of inotropic drugs, i.e.: dopamine >10 µg/kg/min. and/or dobutamine >10* µg */kg/min and/or adrenaline > 0.1* µg*/kg/min*
IABP – intra-aortic balloon pump counterpulsation; p – level of statistical significance

(χ^2 = 41,75; p < 0.001) (Fig. 1). Complete revascularization was performed more frequently in patients undergoing CABG (Table II).

There were no significant differences between the two groups in baseline and postoperative results regarding the emotional state, which is known to affect the cognitive function. The severity of depressive mood assessed with the HADS score was low. The anxiety level in both groups was moderately elevated before surgery (Table III).

In patients undergoing CABG, there was a significant increase in the severity of depressive mood after surgery. By contrast, in the OPCAB group, there were no significant differences in this regard. In both groups, there was a significant drop in the level of anxiety after surgery (Table III). There were no preoperative or postoperative delirium, agnosia, aphasia, alexia, agraphia, acalculia, or apraxia

Tab. III. Emotional state in patients before and after surgery

		Before	After	p
Depressive mood	CABG	3.7 ±2.1	4.4 ±3.1	< 0.01
	OPCAB	3.8 ±2.4	3.6 ±3.0	NS
	p	NS	NS	
Anxiety	CABG	8.4 ±3.4	5.7 ±2.1	< 0.01
	OPCAB	8.8 ±3.8	4.7 ±2.3	< 0.01
	p	NS	NS	

p – statistical significance

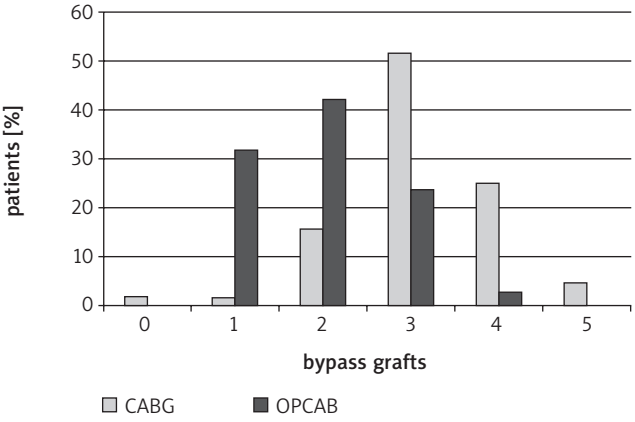

Fig. 1. The number of bypass grafts in both study groups

Tab. IV. The results of neuropsychological tests in both groups before and after surgery

		Before	After	p
AVLT (total of re-called words in trials I-V)	CABG	37.7 ±8.5	32.5 ±9.9	< 0.01
	OPCAB	36.9 ±8.4	36.3 ±8.3	NS
	p	NS	< 0.05	
AVLT after 30 minutes	CABG	7.8 ± 2.5	6.2 ±2.4	< 0.01
	OPCAB	7.8 ± 2.6	7.2 ±2.6	< 0.05
	p	NS	< 0.05	
BVRT number of correct answers	CABG	5.0 ±1.9	5.1 ±2.1	NS
	OPCAB	4.5 ±1.6	5.4 ±1.9	< 0.01
	p	NS	NS	
BVRT number of errors	CABG	7.1 ±3.9	7.0 ±3.9	NS
	OPCAB	7.1 ±3.3	5.8 ±3.3	< 0.01
	p	NS	NS	
FAS – Verbal Fluency Test	CABG	22.2 ±7.7	20.7 ±7.2	< 0.05
	OPCAB	23.0 ±9.2	22.7 ±10.8	NS
	p	NS	NS	
Digit Span Subtest forward	CABG	5.7 ±1.5	5.4 ±1.6	NS
	OPCAB	5.8 ±1.8	6.1 ±1.7	NS
	p	NS	< 0.05	
Digit Span Subtest backward	CABG	4.4 ±1.8	3.7 ±1.5	< 0.01
	OPCAB	4.1 ±1.9	4.2 ±1.9	NS
	p	NS	NS	
TMT part A	CABG	44.5 ±14.1 14.14.1	45.3 ±14.8	NS
	OPCAB	48.6 ±22.4 22.4	42.1 ±13.3	NS
	p	NS	NS	
TMT part B	CABG	95.4 ±45.4	106.7 ±50.2	NS
	OPCAB	88.7 ±89.0	89.0 ±40.7	NS
	p	NS	NS	
TMT recalculated results	CABG	12.7 ±3.7	11.5 ±4.0	< 0.01
	OPCAB	12.8 ±3.5	13.2 ±3.5	NS
	p	NS	NS	
Digit Symbol Test	CABG	30.1 ±11.3	27.3 ±11.6	< 0.01
	OPCAB	30.1 ±10.0	29.1 ±10.7	NS
	p	NS	NS	

AVLT – Auditory Verbal Learning Test; BVRT – Benton Visual Retention Test; TMT – Trail Making Test

symptoms observed in either study group. The results of pre-and post-operative cognitive functions for both groups are presented in Table IV. Based on the results of the AVLT test, a significant post-operative decline was observed in the CABG group in: verbal learning, delayed verbal memory, verbal recognition and active recall. In the OPCAB group, a significant decline was observed only in delayed verbal memory. Direct visual retention assessed with the BVRT test improved post-operatively in the OPCAB group, but not in the CABG group (no significant change).

Verbal fluency assessed with the FAS test deteriorated in the CABG group, whilst in the OPCAB group it remained largely unchanged. Based on the TMT A and B scores, no statistically significant postoperative decline was observed in either group with regard to visual-spatial working memory, visual-motor coordination, top-down attention, or the ability to plan and to switch tasks after having learned a rule. Categorical direct verbal memory and attention assessed with the Digit Span Subtest Forward. Test remained unchanged in both groups. However, the results of the Backward Digit Repetition Test showed a decline in visual and auditory working memory in the CABG group. Digit Span Subtest Backward, a significant postoperative decline was observed in the CABG group with regard to visual learning ability, information processing speed, attention and visual-motor coordination. The direction of changes in the assessed cognitive functions in both groups after myocardial revascularization as compared with baseline results are presented in Table V.

The study showed that an unstable course of disease caused a 2.3-point decrease in verbal fluency assessed with the FAS test (Table VI). In the OPCAB group, visual-spatial working memory and visual-motor coordination improved by 7.5 points (mean, assessed with the TMT A and B tests) as compared with the CABG group. The presence of carotid atherosclerosis caused a mean 8.1 point decline in visual-spatial working memory and visual-motor coordination (regardless of the surgical method: OPCAB or CABG) (Table VII).

Tab. V. Postoperative changes in cognitive function in both groups

Cognitive function	CABG (n = 64)	OPCAB (n = 39)
Top-down attention	↓	–
Direct visual memory	–	↑
Categorical auditory memory	↓	–
Direct verbal memory	–	–
Visual-auditory working memory	↓	–
Visual-spatial working memory	–	–
Delayed verbal memory	↓	↓
Verbal recognition and active recall	↓	–
Auditory learning	↓	–
Visual learning	↓	–
Verbal fluency	↓	–
Visual-motor coordination	↓	–
Planning	–	–
Information processing speed	↓	–

↓ *decline;* ↑ *improvement;* – *no significantly change*

Discussion

The study analysed the changes in cognitive functions and risk factors for cognitive decline in the early postoperative period in a group of patients undergoing elective coronary artery bypass with no simultaneous valve replacement or valvuloplasty. Next, the changes in cognitive functions in patients operated on with and without extracorporeal circulation were compared.

To date, only a few studies have been conducted on cognitive functions in Polish patients undergoing cardiac surgery. The prospective, observational, single surgeon trial conducted by Szwed *et al.* confirmed that "no touch" OPCAB was associated with better attention and executive functions one week after surgery compared with traditional OPCAB [13]. Krysta *et al.* analysed the correlation between the level of anxiety, depression and selected cognitive functions in patients after coronary artery bypass grafting [14]. Unlike numerous other authors, they observed no clear effect of depressive disorders on recent memory, learning, accuracy and continuity of attention, assessed with the Vienna Test System. However, the difference may have been caused by the methodology used to assess cognitive functions, which was different from that of other authors.

There are a few randomized studies comparing the neuropsychological functions in patients undergoing CABG and OPCAB [2-4, 13, 14]. As in our study, the randomized studies described below analysed low-risk patients with restrictive inclusion criteria, excluding patients with acute myocardial infarction, impaired left systolic ventricular function, renal failure, requiring urgent surgery, with a past cardiac surgery or cerebral stroke. In a study conducted by Vedin *et al*. [4] at one week and at 30 days after surgery, cognitive decline was more severe in the CABG than in the OPCAB group. Lee *et al.* did not observe any cognitive decline in patients undergoing CABG and OPCAB at two weeks after surgery [14]. Lloyd *et al.* [13] reported no significant differ-

Tab. VI. Results of multiple regression analysis with backward stepwise procedure for the FAS test

	BETA	SE	t	p	B
unstable course of coronary heart disease	–2.2765	1.1382	–2.0000	< 0.05	–0.2000

Group 1 = OPCAB; Group 0 = CABG; SE – standard error; p – statistical significance

Tab. VII. Results of multiple regression analysis with backward stepwise procedure for the TMT A test

	BETA	SE	t	p	B
surgical method	–7.5251	3.2216	–2.3358	< 0.05	–0.2274
carotid atherosclerosis	8.0676	3.9021	2.0675	< 0.05	0.2012

Group 1 = OPCAB; Group 0 = CABG; SE – standard error; p – statistical significance

ences in cognitive functions between the CABG and OPCAB groups during 12-week follow-up. Zanvar *et al*. compared cognitive functions in patients undergoing CABG or OPCAB at one and ten weeks after surgery [3]. The study showed a significantly smaller percentage of cognitive decline in OPCAB patients [3]. Three controlled clinical trials assessed cognitive functions in the early postoperative period. In a study conducted by German authors, a group of 67 patients treated with CABG was examined before surgery and then at 3, 6 and 9 days after surgery [15]. The authors observed a cognitive decline at 3 days compared to preoperative results but at 9 days noted a gradual recovery of cognitive functions, eventually reaching the preoperative level. Keith *et al*. assessed cognitive functions in 57 patients; the control group was composed of 55 people of a comparable age [5]. In patients qualified for CABG there was a lower baseline level of cognitive functions than in controls. No significant differences in cognitive functions were observed in the analysed group as compared with controls at 3-4 weeks after surgery. Selnes *et al*. [6] analysed 140 patients undergoing CABG and a control group composed of 92 individuals with diagnosed coronary disease. In 12-week follow-up, the authors observed no significant differences in cognitive functions between the groups, the only exception being an improvement in verbal memory in CABG patients. The conclusions that can be drawn from the above-listed studies [5, 6, 15] are that cognitive decline after CABG is transient and reversible, and in most patients cognitive functions return to their baseline levels between the third and twelfth week after surgery. Furthermore, the presence of an early postoperative cognitive decline is a risk factor for such a decline in future. By contrast, Newman *et al*. showed that the significant decrease in the prevalence of cognitive decline six months after CABG, as compared with the early post-operative period, is followed by a significant increase five years later [16].

The second aim of the study was to determine the factors negatively affecting cognitive functions. Based on the conducted analyses, we concluded that unstable course of disease was an independent factor for decline in verbal fluency (assessed with the FAS test). Extracorporeal circulation and carotid artery atherosclerosis were independent factors negatively affecting visual-motor coordination and visual-spatial working memory (assessed with the TMT A test). Ho *et al*. analysed over 900 patients from the multi-centre PSOCS trial (Processes, Structures, and Outcomes of Care In Cardiac Surgery) [7] followed up for six months. In that study, the risk factors for cognitive decline were: neurologic diseases affecting daily activities, vascular brain disease, peripheral vascular disease, living alone and any postoperative complications. Sisillo *et al*. assessed perioperative cognitive functions in 8,000 patients undergoing coronary artery bypass surgery. Based on the conducted analysis, the authors concluded that only past myocardial infarction was a risk factor for cognitive decline [8]. Boothwani *et al*. analysed patients treated with elective coronary artery bypass surgery [17]. A multifactor analysis showed that the factors affecting cognitive functions were: ICU (intensive care unit) stay > 12 h (OR = 1.88), impaired left ventricular function (OR = 1.53), preoperative creatinine level (OR = 1.01), intraoperative normothermia (OR = 1.15) and level of education (OR = 1.52). Sendelbach *et al*. conducted a prospective study assessing cognitive functions 72 h before and after the planned coronary artery bypass surgery without extracorporeal circulation [18]. The authors found that factors influencing the level of postoperative cognitive functions were: age, anxiety, atrial fibrillation and motor function. Mishra et al. analysed risk factors for neurologic complications in patients with aortic atherosclerotic lesions undergoing coronary bypass surgery. The only independent factor increasing the risk of neurologic complications was CABG surgery with extracorporeal circulation (OR = 1.4) [19].

The results of this analysis and the available literature indicate the need to establish an international classification describing the methodology of neuropsychological and functional assessment of patients after cardiac surgery. The classification should be based on the assessment of individual changes in cognitive functions and the assessment of life activity affecting the quality of life [20]. The inclusion of routine neuropsychological diagnosis in the course of treatment of patients undergoing surgical myocardial revascularization seems essential.

Limitations of the study

Based on the MMSE test, we excluded from the analysis patients with signs of dementia connected with cognitive disorders before surgery. Also excluded from the study were patients with depression, as it may cause cognitive impairment. This resulted in lowering the incidence of cognitive impairment in the studied population of patients undergoing coronary bypass surgery. However, this action was deliberate and was aimed at maintaining the homogeneity of the group and at obtaining answers to the questions set as the aims of the study. For the same reason, patients undergoing emergent or urgent surgical myocardial revascularization were also excluded from the study – this group of patients tends to display a higher level of anxiety. Another limitation of the study was the relatively small number of patients, all of whom came from the same centre, and a short follow-up period. The study had originally been planned with a 6-month follow-up; however, almost 80% of the patients were unavailable for neuropsychological assessment after hospital discharge. Another limitation of the study is the lack of randomization.

It is also necessary to look critically at the literature discussed in this article. The analysis of the available medical databases showed that most studies on cognitive impairment in patients after coronary artery bypass grafting date back to 1995-2002, i.e. the period of major interest in the issue worldwide. There are few original articles, review papers and academic manuals available in the Polish literature. Nonetheless, the above-listed limitations did not have a significant effect on achieving the aims of the study.

Conclusions

1. Postoperative cognitive decline was more severe in patients operated on with extracorporeal circulation.
2. In patients operated on with extracorporeal circulation, cognitive decline was observed in top-down attention, categorical auditory memory, visual-auditory working memory, auditory recognition and active recall, visual and auditory learning, verbal fluency, visual-motor coordination and information processing speed. In the group operated on without extracorporeal circulation, cognitive decline was observed only in delayed verbal memory. Unstable course of coronary artery disease is an independent risk factor for postoperative decline in verbal fluency. Carotid artery atherosclerosis and use of extracorporeal circulation are independent risk factors for postoperative decline in visual-spatial working memory and visual-motor coordination.

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