ORIGINAL ARTICLE

Effect of hybrid treatment on rehabilitation and clinical condition of patients with multivessel coronary artery disease

Joanna Foik[1], Anna Brzęk[2], Marek J. Gierlotka[3], Michał O. Zembala[4], Mariusz Gąsior[3], Marian Zembala[4]

1 Department of Rehabilitation, Silesian Center for Heart Diseases, Zabrze, Poland
2 Department of Kinesiology, Chair of Physiotherapy, School of Health Sciences, Medical University of Silesia, Katowice, Poland
3 3rd Department of Cardiology, Medical University of Silesia, Katowice, Silesian Center for Heart Diseases, Zabrze, Poland
4 Department of Cardiac Surgery and Transplantation, Medical University of Silesia, Katowice, Silesian Center for Heart Diseases, Zabrze, Poland

KEY WORDS

clinical condition, coronary artery disease, hybrid revascularization, rehabilitation

ABSTRACT

INTRODUCTION Rehabilitation after coronary revascularization procedures is an intrinsic part of treatment during the in-hospital period.

OBJECTIVES We aimed to compare the course and effects of rehabilitation in patients receiving hybrid treatment (minimally invasive direct coronary artery bypass / percutaneous coronary intervention) or classic treatment (coronary artery bypass grafting / off-pump coronary artery bypass) during hospitalization.

PATIENTS AND METHODS The study included 200 patients participating in a prospective randomized clinical trial (POLMIDES) that assessed the effect of hybrid treatment on in-hospital outcomes and long-term results in patients with multivessel coronary artery disease. Patients were divided into the classic and hybrid groups.

RESULTS The classic group showed a higher perioperative risk than the hybrid group (mean [SD] EuroSCORE, 3.54 [2.12] and 2.89 [1.97], respectively). During all the rehabilitation cycles, lower arterial oxygen saturation (SaO_2) was reported in the hybrid group ($P = 0.002$). The classic group showed lower systolic blood pressure ($P < 0.001$), lower diastolic blood pressure ($P = 0.029$), and a higher rate of blood pressure drops during rehabilitation ($P = 0.02$). Patients from the classic group were able to sit ($P < 0.001$), assume a vertical position ($P < 0.001$), and walk ($P = 0.01$) earlier than those from the hybrid group. In the hybrid group, earlier completion of rehabilitation and discharge from the hospital were noted ($P = 0.001$).

CONCLUSIONS Patients receiving hybrid coronary revascularization less often suffer from hypotonia events but show lower SaO_2 values than patients receiving classic treatment. Mobilization of patients receiving the hybrid treatment is slower during the initial days and cycles of rehabilitation, but they achieve full self-reliance earlier, which enables a shorter hospitalization period.

Correspondence to:
Anna Brzęk, PhD, PT,
Wydział Nauk o Zdrowiu w Katowicach, Zakład Kinezjologii Katedry Fizjoterapii, Śląski Uniwersytet Medyczny w Katowicach, ul. Medyków 12, 40-754 Katowice, Poland,
phone: +48 32 208 87 21,
email: aniabrzek@interia.pl
Received: September 1, 2017.
Revision accepted: January 2, 2018.
Published online: January 2, 2018.
Conflict of interest: none declared.
Pol Arch Intern Med.
doi:10.20452/pamw.4179

INTRODUCTION A hybrid method is a combination of 2 well-established methods for coronary revascularization, surgical and percutaneous, integrating their greatest advantages.[1-3] A decision between conservative or interventional treatment in the case of coronary artery disease (CAD) should depend on the assessment of the benefit-to-risk ratio for these treatment strategies and on a comparison of the risk of death, myocardial infarction, and stroke during the perioperative period, with the expected improvement in the quality of life and long-term decrease in the risk of death, myocardial infarction, and repeat revascularization.

Currently, grafting of the left internal mammary artery (LIMA) to the left anterior descending artery (LAD) is the best method for revascularization of the LAD, and it is associated with high patency of bypasses, reaching over 90% in a 10-year follow-up.[4] Prospective randomized trials comparing percutaneous coronary intervention

(PCI) with implantation of bare-metal stents to LIMA implantation to the proximal LAD segment strongly confirm the superiority of the surgical procedure.[5]

The hybrid method of revascularization in patients with advanced multivessel CAD has been popularized because it is minimally invasive and spares patients from complications associated with cardiopulmonary bypass and median sternotomy that are used during the classic coronary artery bypass graft (CABG) surgery.[6,7] According to the current knowledge, it is expected that the hybrid treatment of these patients will have similar direct effectiveness but with higher safety (eg, lower frequency of bleeding, perioperative myocardial infarctions, and strokes), as well as a shorter duration of hospitalization and rehabilitation.

Rehabilitation of patients depends on the applied revascularization method and constitutes an integral part of the in-hospital treatment. Moreover, the choice of the method to a large extent determines the course of the postoperative period as well as the speed and effects of rehabilitation. The management encompasses the preparation before the procedure (in the case of the classic method) and rehabilitation after the operation.[8,9] Regardless of the applied surgical technique, the management is focused on the same aims: prevention of the effects of immobilization; implementation of the mechanisms of appropriate pulmonary ventilation, cough, and expectoration; and mobilization of patients as soon as possible, such as learning how to change positions and move in bed, especially in patients scheduled for classic revascularization using sternotomy.[10,11]

The benefits of implementing rehabilitation in patients following elective PCI are still underestimated. However, several initiatives in the field have been undertaken, including a study by Martynova et al.[12] Mobilization of the patient depends on whether the procedure is performed using a radial or femoral artery approach. Constant monitoring of the patient during exercise and an individual approach to each patient with regards to concomitant noncardiac diseases influence patient safety and thus the quality and effectiveness of treatment. Rehabilitation during the in-hospital period should not only consider the current physical condition of the patient but also its effect on mental health, social activities, and a possible return to professional work, thus fulfilling one of the essential rules of rehabilitation—comprehensiveness.[13,14]

Data on the rehabilitation of patients treated with the hybrid method during hospitalization are still lacking. The prospective randomized clinical trial POLMIDES,[15] assessing the effect of hybrid treatment on the in-hospital outcomes and long-term results of patients with multivessel CAD, distinguished a new group of patients undergoing rehabilitation during this stage of treatment. The aim of our study was to compare the course and effects of rehabilitation in patients receiving hybrid and classic treatments during the in-hospital period. Selected parameters monitored during the individual cycles of rehabilitation, the pace of mobilization, and the cost of rehabilitation in both study groups were analyzed.

PATIENTS AND METHODS We analyzed patients participating in POLMIDES, a developmental program financed by the National Centre for Research and Development (no. N R13008406/2009, Bioethics Committee approval no. KNW/002/KB1/168/08/0), conducted at the Silesian Center for Heart Diseases in Zabrze, Poland, from November 2009 to December 2013.[15] We enrolled 200 consecutive patients with angiographically documented multivessel CAD with involvement of the LAD, who were referred for arterial revascularization with at least 1 hemodynamically significant lesion (>70%) in the other arteries and who were suitable for PCI and CABG. The inclusion and exclusion criteria of the study are presented in **TABLE 1**.

Randomization In the main POLMIDES study, patients meeting the inclusion criteria were randomly assigned to 2 treatment groups. The first group consisted of 98 patients subjected to hybrid revascularization in 2 treatment stages. The first stage included grafting of the arterial bypass of the LIMA to the LAD, using the minimally invasive direct coronary artery bypass (MIDCAB) / endoscopic atraumatic coronary artery bypass technique. The second stage consisted of the PCI procedure with implantation of stents coated with antimitotic drugs to the remaining coronary arteries that were subjected to treatment within 36 hours from the completion of the first stage. The second group included 102 patients who underwent conventional surgical revascularization with or without the use of cardiopulmonary bypass. Six patients who had been previously randomized to the hybrid group required conversion to the full CABG and were assigned to the classic group.

Finally, 92 patients in the hybrid group (MIDCAB + PCI) and 108 patients in the classic group (CABG / off-pump coronary artery bypass [OPCAB]) were analyzed. All patients were screened by a local heart team (at least 1 interventional cardiologist and a cardiothoracic surgeon). The heart team checked all the inclusion and exclusion criteria and the eligibility of patients to undergo MIDCAB + PCI. Eligible patients were randomized in a 1:1 fashion to hybrid or standard surgical treatment, using closed envelopes. The study protocol was approved by the local ethics committee and complied with the Declaration of Helsinki. All study participants provided written informed consent to enrollment and data collection.

Rehabilitation management scheme The initial rehabilitation management scheme for patients

TABLE 1 Study inclusion and exclusion criteria

Inclusion criteria
Multivessel CAD, documented by angiography, with involvement of the LAD and critical (>70%) lesions in at least 1 major epicardial artery, apart from the LAD, eligible for PCI and CABG
Indications for revascularization based on clinical assessment or objective ischemic features
Age >18 years
Informed consent to participate in the study
Exclusion criteria
Severe heart failure (NYHA class III or IV), pulmonary edema, cardiogenic shock at randomization, prior surgical procedure requiring the opening of pericardial sac and/or pleural cavities
Significant bleeding in the last 6 months, posing a risk for recurrence of bleeding during anticoagulant therapy associated with PCI/CABG
More than 1 chronic total occlusion in major epicardial arteries except the LAD
Left coronary artery trunk stenosis >50%
STEMI within 72 hours before randomization requiring urgent revascularization
Stroke in the last 6 months (or earlier in the case of significant neurological deficits)
Planned simultaneous surgical procedure apart from revascularization (eg, valve replacement/repair, aneurysmectomy, endarterectomy of the carotid artery, or carotid artery stenting)
Significant leukopenia, neutropenia, thrombocytopenia, anemia, or other serious hematological disorder
Intolerance of, contraindications to, or resistance to treatment with aspirin, clopidogrel, or ticlopidine
Extracardiac conditions with predicted survival shorter than 5 years (eg, COPD depending on passive oxygen therapy, active hepatitis, hepatic failure, severe renal disease)
Pregnancy or suspicion of pregnancy
Lack of informed consent to participate in the study

Abbreviations: CABG, coronary artery bypass grafting; CAD, coronary artery diseas; LAD, left anterior descending artery; NYHA, New York Heart Association; PCI, percutaneous coronary intervention; COPD, chronic obstructive pulmonary disease; STEMI, ST-segment elevation myocardial infarction

from both study groups, presented in FIGURE 1, was modified depending on the patient's clinical condition and periprocedural complications.

Preparation before the procedure Preparation started on the day of hospital admission, 1 day before the planned surgical procedure. Each patient was provided with all the essential information concerning the course of rehabilitation in the postoperative period, such as learning the "effective cough" and methods of stabilization of the sternum or the postoperative wound depending on the surgical technique applied. Moreover, patients were taught how to change positions and move in bed, and the purpose of using analgesic agents was explained

Rehabilitation cycles Rehabilitation was started after extubation and was continued throughout the whole hospitalization. A rehabilitation cycle included the following: chest percussion facilitating evacuation of bronchial secretion; cough stimulation preceded by sternum or wound stabilization, depending on the surgical technique applied; breathing exercises improving lung ventilation, with the use of breathing exercise devices; active exercises, general mobility exercises done by the patient under the guidance of a physiotherapist (instruction); and gradual controlled mobilization of the patient, starting from sitting in the bed in the cardiological (armchair) position through sitting on the bed with legs down, verticalization, walking with the assistance of the physiotherapist, and unassisted walking without restrictions, also on the stairs.

Day 1 after the procedure Three monitored rehabilitation cycles were applied: cycle 1 in the morning, cycle 2 at noon, and cycle 3 in the afternoon. Patients from the hybrid group omitted one of the cycles because they were at a hemodynamic laboratory at that time for the second stage of treatment according to the protocol of the POLMIDES trial (PCI up to 36 hours after the MIDCAB procedure). Patients presenting with symptoms of evident circulatory failure, those returning to the operating theatre due to bleeding, or those with other contraindications to exercise were also excluded from rehabilitation at certain cycles.

Day 2 after the procedure Two monitored cycles of rehabilitation were applied: cycle 4 in the morning and cycle 5 in the afternoon. A patient was encouraged to repeat breathing exercises and unassisted motor activity after drainage removal. Patients from the hybrid group subjected to PCI were mobilized after the removal of pressure dressing from the femoral artery.

Day 3 after the procedure One cycle of rehabilitation, cycle 4, was conducted in the morning. The aim of rehabilitation was to achieve full independent mobility by the patient.

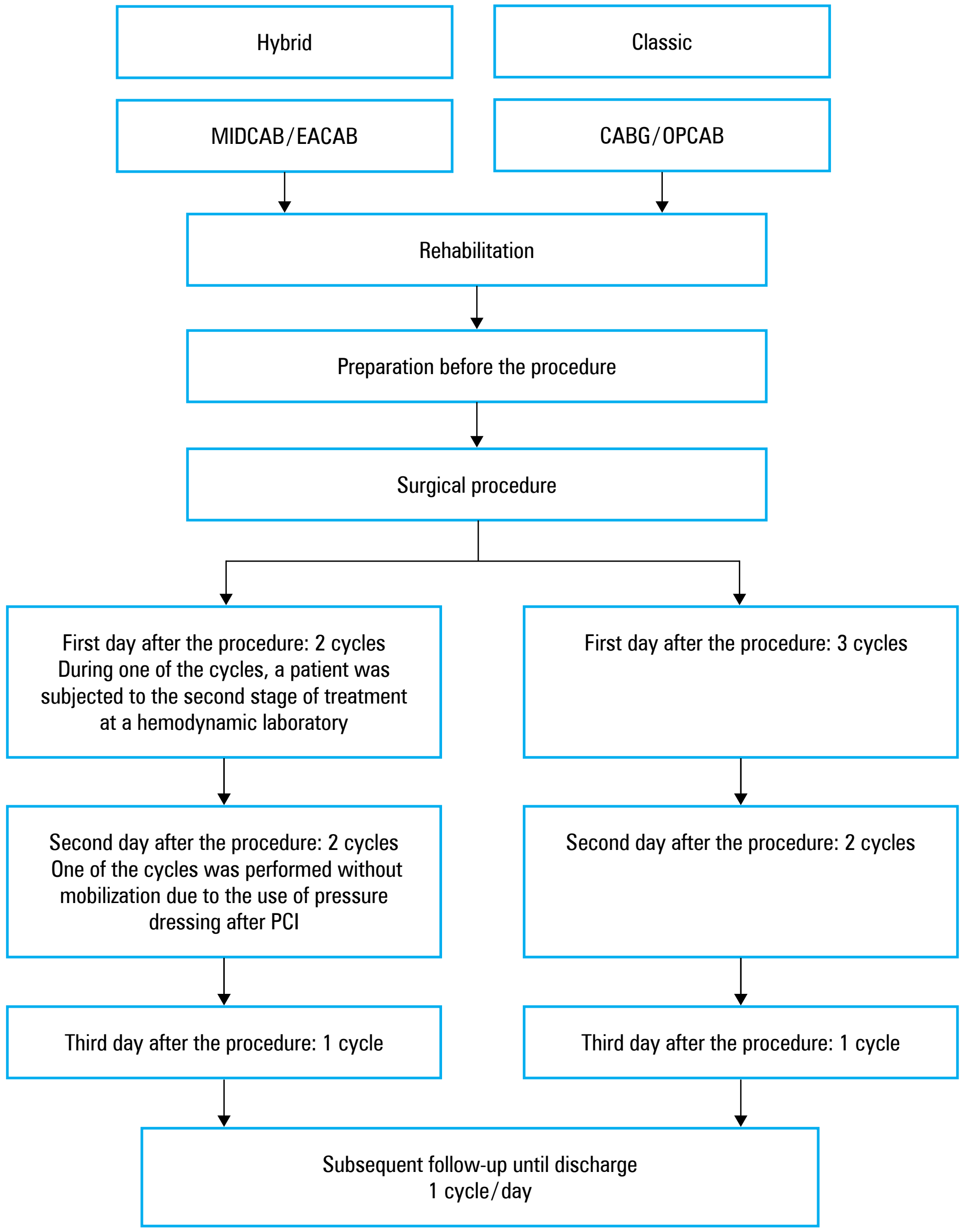


FIGURE 1 Rehabilitation regimen during hospitalization
Abbreviations: CABG, coronary artery bypass grafting; EACAB, endoscopic atraumatic coronary artery bypass technique; MIDCAB, minimally invasive direct coronary artery bypass; OPCAB, off-pump coronary artery bypass; others, see **TABLE 1**

Subsequent follow-up Breathing and general mobility rehabilitation were continued until discharge from the hospital. The exercises were aimed at improving the patient's physical capacity and breathing capacity. Patients were encouraged to prolong the distance and pace of walking through the corridor and on the stairs. They were also educated on the management at home, further convalescence, and a healthy lifestyle. Education concerned the risk factors for cardiovascular diseases and the methods of disease control, the role of physical activity in both prevention and postoperative treatment, and dietary recommendations. Each patient received home health counseling after discharge, including advice on worrying symptoms during exercise in the early postoperative period.

Analysis of clinical factors During the in-hospital period, the following clinical factors were analyzed: age, sex, height, body weight, body mass index, arterial hypertension, diabetes, hyperlipidemia, cigarette smoking, previous myocardial infarction, grade of angina pectoris according to the Canadian Cardiovascular Society classification, heart failure stage according to the New York Heart Association classification, left ventricular ejection fraction, European System for Cardiac Operative Risk Evaluation (EuroSCORE), and the SYNTAX score. The following biochemical parameters were also analyzed: glomerular filtration rate, total cholesterol, high-density lipoprotein cholesterol, low-density lipoprotein cholesterol, and triglycerides.

The parameters monitored in the individual cycles of rehabilitation were as follows: arterial blood pressure, systolic and diastolic blood pressures, heart rate, the use of pressor amines, occurrence of chest and sternum pain, blood pressure drops during rehabilitation, and occurrence of atrial fibrillation (AF).

TABLE 2 Clinical parameters of the study groups at baseline

Parameter		Hybrid MIDCAB + PCI (n = 92)	Classic CABG/OPCAB (n = 108)	*P* value
Age, y		62.6 (8.2)	64.3 (8.4)	0.16
Sex	Men, n (%)	72 (78.3)	79 (73.1)	0.40
	Women, n (%)	20 (21.7)	29 (26.9)	
Height, cm		169.5 (8.3)	168.1 (7.3)	0.21
Body weight, kg		81.1 (12.2)	82.2 (12.7)	0.56
BMI, kg/m²		28.2 (3.4)	29.0 (4.1)	0.13
Hypertension, n (%)		81 (88.0)	90 (83.3)	0.35
Diabetes, n (%)		23 (25.0)	33 (30.6)	0.38
Hyperlipidemia, n (%)		51 (55.4)	65 (60.2)	0.50
Smoking, n (%)		22 (23.9)	36 (33.3)	0.14
Previous myocardial infarction, n (%)		46 (50.0)	65 (60.2)	0.15
CCS grade, n (%)	I	6 (6.5)	4 (3.7)	0.32
	II	51 (55.5)	63 (58.3)	
	III	35 (38.0)	38 (35.2)	
	IV	–	3 (2.8)	
NYHA class, n (%)	I	58 (63.0)	60 (55.6)	0.55
	II	33 (35.9)	47 (43.5)	
	III	1 (1.1)	1 (0.9)	
EF, %		50.5 (5.8)	50.2 (7.5)	0.78
EuroSCORE		2.89 (1.97)	3.54 (2.12)	0.028
SYNTAX score		23.3 (6.4)	23.0 (5.4)	0.69
GFR, ml/min/1.73 m²		92.1(20.8)	88.8 (24.1)	0.31
TC, mmol/l		5.07 (1.40)	5.06 (1.17)	0.96
HDL-C, mmol/l		1.26 (0.30)	1.31 (0.52)	0.42
LDL-C, mmol/l		3.0 (1.13)	3.06 (0.97)	0.70
TG, mmol/l		1.82 (1.15)	1.73 (1.06)	0.62
Adverse vascular events, n (%)		1 (1.09)	3 (2.78)	0.63
Renal insufficiency, n (%)		–	1 (0.93)	1.0
Delirium, n (%)		–	3 (2.78)	0.25
Transfusion of blood preparations, n (%)		14 (15.22)	32 (29.63)	0.016
Perioperative myocardial infarction, n (%)		5 (5.43)	4 (3.79)	0.56
Stroke, n (%)		–	–	–
Death, n (%)		–	–	–

Data are presented as mean (SD) unless otherwise stated. A *P* value of 0.05 or lower was considered significant.

Abbreviations: BMI, body mass index; CCS, Canadian Cardiovascular Society; EF, ejection fraction; GFR, glomerular filtration rate; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TC, total cholesterol; TG, triglycerides; others, see TABLE 1 and FIGURE 1

The analyzed stages of gradual mobilization included sitting in the cardiological position, active verticalization, the first walk, and unassisted walking without restrictions.

Cost analysis The costs of rehabilitation during the in-hospital period were estimated based on data from resource allocation and cost calculation at the Silesian Center for Heart Diseases. These data included the scope of costs of each rehabilitation procedure, including both personnel costs and the costs of breathing exercise devices.

The analysis was conducted for each patient individually, and a comparison was made providing the average costs calculated per patient in Polish zlotys.

Statistical analysis The studied groups were compared with respect to anthropometric parameters, concomitant diseases, and clinical factors, and the effects of treatment during the in-hospital period were compared with the results of parameters monitored in the individual cycles of rehabilitation. The stages of gradual mobilization were compared depending on the postoperative day and cycle of rehabilitation, and the costs of rehabilitation in both study groups were also analyzed.

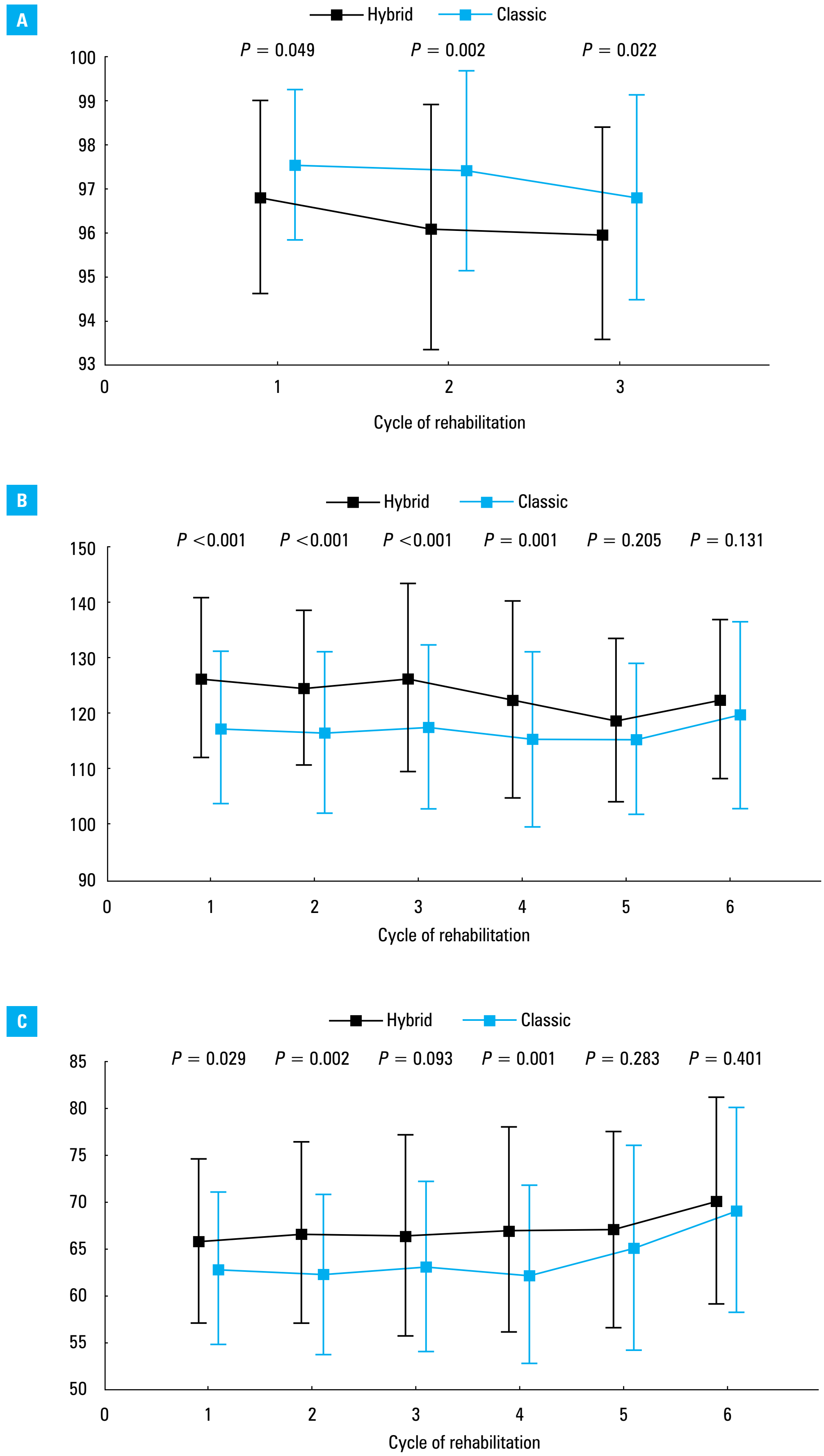
Continuous parameters with a normal distribution were presented as means with SD, and the significance of differences between the groups was assessed by the *t* test. Continuous parameters with a nonnormal distribution were presented as medians, and the significance of differences between the groups was assessed by the Mann–Whitney test. Qualitative parameters were presented as percentages, and the significance of differences between the groups was assessed by the χ^2 test (in the case of expected frequencies, <5 Yates correction was applied). A *P* value of 0.05 or less was considered significant.

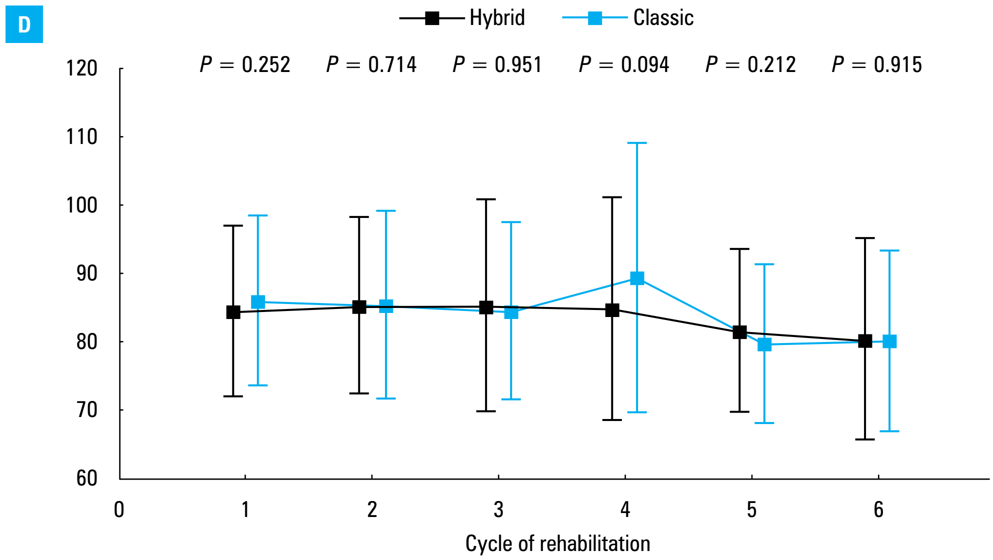
RESULTS

Analysis of the individual rehabilitation cycles The characteristics of the study groups are presented in TABLE 2. The groups were homogeneous in terms of the assessed parameters; the only difference was a higher perioperative risk in the group of patients undergoing classic CABG ($P = 0.028$), as assessed by the EuroSCORE. Death or neurological complications such as stroke were not reported in any of the groups (TABLE 2). The classic group significantly more often required transfusion of blood preparations (29.63% vs 15.22%).

During the 3 monitored cycles (FIGURE 2A), the hybrid group showed lower SaO_2 than the classic group ($P = 0.049$ for cycle 1, $P = 0.002$ for cycle 2, and $P = 0.02$ for cycle 3). In the classic group, systolic blood pressure was lower than that in the hybrid group in cycles 1 to 4 ($P \leq 0.001$) (FIGURE 2B), and diastolic blood pressure was lower in all the cycles (FIGURE 2C). No significant differences in heart rate were observed between the groups during any of the cycles (FIGURE 2D). In the group undergoing classic CABG, pressor amines were more frequently used in all cycles except the last one in which this parameter was not studied per the trial's protocol. The hybrid group showed significantly lower SaO_2 in cycles 2 and 3. The selected parameters monitored during all the cycles of rehabilitation are presented in Supplementary material, *Figure S1*. Because SaO_2 was not monitored in cycle 4, these results were not analyzed. In cycle 4, AF occurred significantly more often in the classic group than in the hybrid group (17.8% vs 5.7%). In cycles

FIGURE 2 Analysis of trends in the analyzed parameters in the individual cycles of rehabilitation; **A** – arterial oxygen saturation; **B** – systolic blood pressure; **C** – diastolic blood pressure; **D** – heart rate





5 and 6, most parameters were similar between the groups except for the use of pressor amines in cycle 5 (TABLE 3). Lower SaO_2 values were observed in patients undergoing lateral thoracotomy compared with those undergoing median sternotomy (mean [SD], 96.13% [2.77%] vs 97.43% [2.27%]; $P = 0.002$).

Comparison of stages of gradual mobilization depending on the postoperative day and cycle of rehabilitation Patients from the classic group were able to sit (P <0.001), remain vertical (P <0.001), and walk ($P = 0.01$) earlier than those in the hybrid group. However, completion of rehabilitation and discharge from the hospital occurred earlier in the hybrid group ($P = 0.001$) (TABLE 4). A slower pace of mobilization during the first 2 days after the procedure in the hybrid group was associated with the second stage of treatment at the hemodynamic laboratory and the necessity to immobilize the patient until the removal of the pressure dressing. However, this slower pace did not influence the mean (SD) duration of rehabilitation and hospitalization, which was shorter in the hybrid group than in the classic group (TABLE 4). The number of cycles of rehabilitation on the first day after the procedure was lower in the hybrid group than in the classic group (mean [SD], 2.09 [0.44] vs 2.96 [0.19]; P <0.001), as was the total number of cycles during hospitalization (mean [SD], 6.70 [3.93] vs 8.45 [6.95]; P <0.001).

Costs of rehabilitation The analyzed rehabilitation procedures performed during hospitalization included active general mobility exercises, breathing exercises, breathing kinesiotherapy, and mobilization (sitting, active verticalization, walking with the assisstance of the physiotherapist).

The costs of the rehabilitation procedures (including the breathing exercise devices, such as a bottle with water for exhale-resisting exercises and a TRI-FLO apparatus for inhale-resisting exercises; sternum belt; and other costs, including personnel costs) are presented in TABLE 5. The mean (SD) costs of the procedures calculated per patient were lower in the hybrid group than in the classic group (P <0.001). The costs of breathing exercise devices calculated per patient were also lower in the hybrid group than in the classic group (32.87 PLN vs 76.58 PLN). Finally, the total costs of rehabilitation were also lower in the hybrid group than in the classic group.

Number of patients in individual cycles of rehabilitation The groups differed in the number of patients participating in the individual cycles of rehabilitation. This resulted from the fact that in the hybrid group, during the first 3 cycles, most patients were undergoing the second stage of treatment at the hemodynamic laboratory and did not participate in those particular cycles. Moreover, patients presenting with circulatory or respiratory failure, patients returning to the operating theatre due to bleeding, or those with other contraindications to exercise were excluded from rehabilitation in both groups. In cycle 6, several patients from the classic and hybrid groups underwent rehabilitation in a cardiac surgery department. Finally, some patients achieved stable clinical condition and full self-reliance earlier, and they were no longer monitored during the final cycles of rehabilitation.

DISCUSSION

Current data on hybrid treatment and rehabilitation of patients with multivessel coronary artery disease The PubMed, Medline, and MESH databases were searched using the terms “hybrid treatment” and “multivessel coronary artery disease”. “Rehabilitation” and “in-hospital stage” filters were applied for the period from January 2005 to May 2017, without linguistic restrictions, and the databases of medical libraries in the Silesian region were also searched. We identified few papers assessing this method of treatment or comparing the hybrid method of revascularization with classic CABG. According to the literature, hybrid treatment is an effective and safe method associated with minimal risk. No studies

TABLE 3 Results of the individual cycles of rehabilitation (1–6) in the study groups (continued on the next page)

Cycle of rehabilitation	Parameter	Hybrid MIDCAB + PCI	Classic CABG/OPCAB	*P* value
1	n	55	107	–
	SaO_2, %	96.82 (2.18)	97.55 (1.71)	0.049
	SBP, mm Hg	126.6 (14.37)	117.50 (13.69)	<0.001
	DBP, mm Hg	65.85 (8.78)	62.94 (8.15)	0.029
	HR, bpm	84.38 (12.49)	86.00 (12.40)	0.25
	Pressor amines, n (%)	3 (5.5)	17 (15.9)	0.097
	Pain, n (%)	6 (10.9)	21 (19.6)	0.23
	Arterial BP drops, n (%)	1 (1.8)	4 (3.7)	0.85
	AF, n (%)	1 (1.8)	3 (2.8)	0.88
2	n	62	107	–
	SaO_2, %	96.13 (2.77)	97.43 (2.27)	0.002
	SBP, mm Hg	124.67 (13.85)	116.69 (14.65)	<0.001
	DBP, mm Hg	66.74 (9.71)	62.30 (8.57)	0.002
	HR, bpm	85.35 (12.91)	85.34 (13.79)	0.71
	Pressor amines, n (%)	1 (1.6)	17 (15.9)	0.008
	Pain, n (%)	8 (12.9)	21 (19.6)	0.36
	Arterial BP drops, n (%)	2 (3.2)	4 (3.7)	0.79
	AF, n (%)	2 (3.2)	4 (3.7)	0.79
3	n	75	106	–
	SaO_2, %	96.00 (2.41)	96.82 (2.33)	0.02
	SBP, mm Hg	126.6 (16.95)	117.68 (14.76)	<0.001
	DBP, mm Hg	66.44 (10.79)	63.15 (9.00)	0.09
	HR, bpm	85.23 (15.67)	84.44 (12.99)	0.95
	Pressor amines, n (%)	2 (2.7)	14 (13.2)	0.028
	Pain, n (%)	8 (10.7)	16 (15.1)	0.52
	Arterial BP drops, n (%)	2 (2.7)	7 (6.6)	0.39
	AF, n (%)	4 (5.3)	6 (5.7)	0.81
4	n	88	106	–
	SaO_2, %	–	–	–
	SBP, mm Hg	122.53 (17.72)	115.41 (15.87)	0.002
	DBP, mm Hg	67.08 (10.96)	62.24 (9.45)	0.001
	HR, bpm	84.82 (16.38)	89.35 (19.78)	0.09
	Pressor amines, n (%)	1 (1.1)	15 (14.1)	0.003
	Pain, n (%)	5 (5.7)	10 (9.4)	0.48
	Arterial BP drops, n (%)	6 (6.8)	12 (11.32)	0.41
	AF, n (%)	5 (5.7)	19 (17.92)	0.018
5	n	85	106	–
	SaO_2, %	–	–	–
	SBP, mmHg	118.83 (14.74)	115.44 (13.59)	0.21
	DBP, mm Hg	67.12 (10.50)	65.18 (10.93)	0.28
	HR, bpm	81.62 (12.00)	79.60 (11.67)	0.21
	Pressor amines, n (%)	1 (1.2)	13 (12.3)	0.007
	Pain, n (%)	5 (5.9)	8 (7.5)	0.84
	Arterial BP drops, n (%)	3 (3.5)	11 (10.4)	0.12
	AF, n (%)	4 (4.7)	8 (7.5)	0.59

TABLE 3 Results of the individual cycles of rehabilitation (1–6) in the study groups (continued from the previous page)

Cycle of rehabilitation	Parameter	Hybrid MIDCAB + PCI (n = 55)	Classic CABG/OPCAB (n = 107)	*P* value
6	n	99	101	–
	SaO_2, %	–	–	–
	SBP, mm Hg	122.59 (14.28)	119.73 (16.90)	0.13
	DBP, mm Hg	70.17 (11.02)	69.12 (10.93)	0.51
	HR, bpm	80.36 (14.74)	79.99 (13.35)	0.91
	Pressor amines, n (%)	–	–	–
	Pain, n (%)	–	–	–
	Arterial BP drops, n (%)	2 (2.0)	9 (8.9)	0.09
	AF, n (%)	6 (6.1)	11 (10.9)	0.44

Data are presented as mean (SD) unless otherwise stated. A *P* value of 0.05 or lower was considered significant.

Abbreviations: AF, atrial fibrillation; BP, blood pressure; DBP, diastolic blood pressure; HR, heart rate; SaO_2, arterial oxygen saturation; SBP, systolic blood pressure

TABLE 4 Stages of gradual mobilization the day after the procedure and in each cycle of rehabilitation

	Stages of gradual mobilization	Hybrid MIDCAB + PCI (n = 92)	Classic CABG/OPCAB (n = 108)	*P* value
Day after the procedure	Sitting in the cardiological position	1.25 (0.81)	1.02 (0.19)	<0.001
	Active verticalization	2.43 (1.08)	1.41 (1.14)	<0.001
	First walk with the physiotherapist	3.05 (1.42)	2.79 (1.37)	0.010
	Unassisted walking	4.10 (2.45)	4.55 (3.75)	0.15
	Discharge	6.74 (3.67)	7.41 (4.93)	0.001
Cycle of rehabilitation	Sitting in the cardiological position	1.77 (1.60)	1.05 (0.32)	<0.001
	Active verticalization	4.23 (1.70)	2.88 (2.25)	<0.001
	First walk with the physiotherapist	5.28 (2.13)	5.43 (2.50)	0.58
	Unassisted walking	6.41 (3.62)	7.52 (6.39)	<0.001

Data are presented as mean (SD). A *P* value of 0.05 or lower was considered significant.

Abbreviations: see TABLES 1 and FIGURE 2

that directly compared the results of rehabilitation after the hybrid strategy for multivessel CAD were found. Importantly, our paper is the first randomized study on this topic. Therefore, our comparative analysis of the course of rehabilitation seems to be completely reliable.

The studied groups did not differ in terms of the assessed parameters except the EuroSCORE (P <0.05). The EuroSCORE did not differ between the originally randomized groups, analyzed by the intention-to-treat principle (per protocol, as they were randomized). However, in the current analysis, the groups were selected as the patients were treated (not as they were randomized), which explains the difference in the EuroSCORE. In our opinion, this one difference did not affect the similarity between the groups in a meaningful way. Although the difference was significant, the absolute difference between the groups was only 0.15 points. Moreover, we did not define any outcome measures in our study. All the results were presented, analyzed, and discussed. Most of them were the average values of the continuous variables, and not the binary data. Therefore, we did not adjust the results of our study for the small absolute difference in the EuroSCORE.

Results of treatment with hybrid revascularization

The characteristics, treatment, and outcomes of patients with acute coronary syndromes in Poland were reported by Poloński et al[16] and Zembala et al.[17] In a study by Harskamp et al,[18] hybrid coronary revascularization (HCR) was associated with a significantly lower number of complications during the in-hospital period compared with CABG; however, during a 3-year follow-up, mortality rates observed after HCR and CABG were similar.

In a meta-analysis by Peng Zu et al,[19] including patients from various centers, hybrid revascularization was compared with classic CABG. No significant differences in the rates of mortality, myocardial infarction, stroke, AF, or renal insufficiency were found during the in-hospital period or after a 12-month follow-up.

TABLE 5 Cost of the in-hospital rehabilitation in the study groups

Rehabilitation	Hybrid MIDCAB + PCI (n = 92)		Classic CABG/OPCAB (n = 108)		*P* value
	Amount	Value, PLN	Amount	Value, PLN	
Active exercises	4.70 (2.47)	46.14	6.14 (4.50)	60.47	<0.001
Breathing exercises	5.93 (3.29)	58.01	7.90 (6.45)	77.87	<0.001
Mobilizations (verticalization, walking)	4.01 (2.30)	26.11	5.50 (3.65)	36.19	<0.001
Total cost of the procedures	–	130.25 (59.93)	–	174.53 (129.36)	<0.001
Other costs	–	118.14	–	118.14	1.0
Breathing exercise devices					
Bottle + hose	0.5	4.69	1.0	9.39	<0.001
TRI-FLO apparatus	0.9	28.18	0.07	2.19	<0.001
Sternum belt	–	–	1.0	65	<0.001
Total cost of rehabilitation	–	281.26	–	369.25	<0.001

Data are presented as mean (SD) or mean. A *P* value of 0.05 or lower was considered significant.

Abbreviations: see TABLES 1 and 2

In the 12-month follow-up of the POLMIDES trial, the rates of mortality, myocardial infarction, bleeding, and the necessity for repeat revascularization were similar between the hybrid and classic treatment groups. No cerebral accidents were observed in the groups either. The limitations of the study included a pilot design and a follow-up of only 12 months, which was not long enough to illustrate the long-term effect of CABG compared with HCR, with respect to major cardiac events. In our study, we did not compare differences in the rates of mortality between the groups either.

Factors influencing early postoperative rehabilitation From a practical point of view, the most important factor during rehabilitation is the patient's clinical condition. In the early postoperative period, monitoring essential vital signs (SaO_2, arterial blood pressure, and heart rate) is required to detect any potential threats and thus conduct rehabilitation in a safe way.[20] The pace of rehabilitation largely depends on the use of pressor amines and the presence of irregular heartbeat (AF), pain, and blood pressure drops during exercise.

AF worsens the patient's clinical condition and prolongs the duration of hospitalization.[21,22] Siebert et al[23] compared the occurrence of AF in patients after CABG and OPCAB and reported no differences between the groups. When analyzing the occurrence of AF in our own study during the 6 cycles of rehabilitation, only a trend towards a rarer occurrence of AF in the hybrid group was observed.

Regardless of the applied surgical technique, pain always occurs during the postoperative period. However, the median sternotomy approach is associated with less pain than lateral thoracotomy.[24] Mechanical ventilation of one lung during the procedure can pose a high risk of hypoxia as a result of gas exchange disorders in the lungs. Our results for SaO_2 confirm that the ventilation of one lung and an increase in pain in patients undergoing minimally invasive procedures affect SaO_2 values during the early postoperative period.

Effects of applied revascularization techniques The postoperative period is often associated with rapid fluctuations in cardiac hemodynamic parameters. An advantage of minimally invasive procedures performed without cardiopulmonary bypass is, apart from a lower demand for blood products, a less frequent use of catecholamines. Kucewicz et al[25] compared the perioperative management and results of treatment in patients operated by the classic method without cardiopulmonary bypass. Catecholamines were administered to 18% of patients in the CABG group and to 9% of those in the OPCAB group. In our own studies, pressor amines were also used significantly more often in patients who received classic revascularization. The use of pressor amines, especially at higher doses (>5 mg/kg/min), prolongs hospitalization at the intensive care unit and delays the patient's mobilization, as compared with standard management without the use of amines.

Fluctuations in arterial blood pressure in the early period after revascularization can be caused by different factors. In patients undergoing a classic surgery, it can result from the adverse effect of cardiopulmonary bypass. In patients undergoing MIDCAB procedures, despite not using cardiopulmonary bypass, significant fluctuations in cardiac hemodynamic parameters are often observed both before and after the surgical procedure. Performing the procedure with this technique is associated with the necessity of opening the pleural cavity during the procedure, which causes pneumothorax and thus cardiopulmonary disorders, depending on the size and duration of the pneumothorax.[20,25] During the 6 cycles of rehabilitation, the classic group showed a tendency for lower systolic and diastolic blood pressures.

Regardless of the surgical technique, the symptoms of orthostatic hypotonia should be considered during the first verticalization. Orthostatic hypotonia more often occurs in elderly patients[26,27] and those who had been immobilized for a longer time before the procedure due to unstable hemodynamic conditions, angina symptoms, or the need for support with an intra-aortic balloon pump. In our study, blood pressure drops during rehabilitation were significantly more frequent in the classic group.

Heart rate is affected mostly by significant postoperative pain, stress, and continuous adrenergic stimulation leading to tachycardia. Systemic inflammatory response syndrome occurs in most patients with cardiopulmonary bypass and is another factor contributing to accelerated heart rate.[20] In our study, no significant differences in heart rate during any of the cycles of rehabilitation were observed.

The hybrid method used in our study consists of 2 stages. After the second stage of treatment, the patient has to be immobilized again. Therefore, there are concerns that this approach to revascularization can prolong rehabilitation and thus the hospitalization period, which may lead to an increase in treatment costs. In the study by Harskamp et al,[18] the average period between the 2 stages of treatment was 3 days. In the POLMIDES trial, the average period from the completion of MIDCAB to PCI was 21 hours.[7,17] This resulted in only a slight delay in the mobilization of patients treated with this method during the first 2 days after the procedure compared with those treated with the classic method. However, it ultimately did not cause any extension of the rehabilitation or hospitalization period. In fact, hospitalization was significantly shorter in the hybrid group.

To our knowledge, our study is the first to investigate this issue and our results need to be confirmed in large randomized studies. However, this strategy of revascularization is currently recommended in everyday clinical practice. The main limitation of the study is a relatively small sample size, which was caused by the exclusion of patients with left coronary artery trunk disease, heart failure, and left ventricular ejection fraction of less than 35% as well as the fact that participants were recruited from a single center.

Conclusions Patients receiving the hybrid treatment required administration of pressor amines less frequently and less often experienced hypotonia. On the other hand, SaO_2 values were significantly lower in this group compared with the group receiving the classic treatment. Mobilization of patients in the 2-stage regimen of hybrid treatment was slower during the first 2 days and cycles of rehabilitation, but these patients achieved full self-reliance earlier than those from the classic group.

ACKNOWLEDGMENTS The study was funded by the National Centre for Research and Development No. N R13008406/2009 and the Medical University of Silesia (KNW/002/KB1/168/08/0; to MZ and MG).

CONTRIBUTION STATEMENT MG and JF conceived the concept of the experiments, designed the experiments, and contributed to research design. JF performed the experiments. MG, JF, and AB conceived the concept of the study. JF and MJG analyzed the data. JF, AB, and MOZ prepared the figures and tables. MG and MZ critically revised the manuscript. All authors contributed to data interpretation, the writing and editing of the manuscript, and approving the final version of the manuscript.

SUPPLEMENTARY MATERIAL Supplementary material is available with the online version of the article at www.pamw.pl.

REFERENCES

1 Zembala M, Tajstra M, Zembala MO, et al. Has the time come for hybrid revascularisation in multivessel coronary artery disease? Kardiol Pol. 2009; 67: 817-822.

2 Cisowski M, Morawski W, Drzewiecki J, et al. Integrated minimally invasive direct coronary artery bypass grafting and angioplasty for coronary artery revascularization. Eur J Cardiothorac Surg. 2002; 22: 261-265.

3 ESC/EACTS guidelines on myocardial revascularization 2014. Kardiol Pol. 2014; 72: 1253-1379.

4 Loop FD. Internal thoracic artery grafts. Biologically better coronary arteries. N Eng J Med. 1996; 334: 263-265.

5 Diegeler A, Thiele H, Falk V, et al. Comparison of stenting with minimally invasive bypass surgery for stenosis of the left anterior descending coronary artery. N Engl J Med. 2002; 347: 61-66.

6 Kappetein AP, Head SJ. CABG, stents, or hybrid procedures for left main disease? EuroIntervention. 2015; 11: 111-114.

7 Gąsior M, Zembala MO, Tajstra M, et al. Hybrid revascularization for multivessel coronary artery disease. JACC Cardiovascular Interv. 2014; 7: 1277-1283.

8 Kuch M. Cardiology Rehabilitation. Warszawa: Medical Education; 2014: 270-276.

9 Dylewicz P, Jegier A, Piotrowicz R, et al. Comprehensive cardiac rehabilitation. Folia Cardiologica. 2004; 11: 32-41.

10 Dong Z, Yu B, Zhang Q, et al. Early rehabilitation therapy is beneficial for patients with prolonged mechanical ventilation after coronary artery bypass surgery. Int Heart J. 2016; 57, 2: 241-246.

11 Pantoni CB, Di Thommazo-Luporini L, Mendes RG, et al. Continuous positive airway pressure during exercise improves walking time in patients undergoing inpatient cardiac rehabilitation after coronary artery bypass graft surgery: a randomized controlled trial. J Cardiopulm Rehabil Prev. 2016; 36: 20-27.

12 Martynova VV, Andreev DA, Doletskiĭ AA, et al. Early physical rehabilitation after elective percutaneous coronary interventions during incomplete revascularization: exercise regimen calculation by ergospirometry. Ter Arkh. 2013; 85: 23-28.

13 da Costa Torres D, Dos Santos PM, Reis HJ, et al. Effectiveness of an early mobilization program on functional capacity after coronary artery bypass surgery: A randomized controlled trial protocol. SAGE Open Med. 2016; 4: 1-8.

14 Goel K, Lennon RJ, Tilbury T, et al. Impact of cardiac rehabilitation on mortalite and cardiovascular events after percutaneous intervention in the comunity. Circulation. 2011; 123: 2344-2355.

15 Poloński L, Gąsior M, Gierlotka M, et al. What was changed in the treatment of ST- segment elevation myocardial infraction in Poland in 2003-2009? Data from the Polish Registry of Acute Coronary Syndromes (PL--ACS). Kardiol Pol. 2011; 161: 1109-1118.

16 Poloński L, Gąsior M, Gierlotka M, et al. Polish Registry of Acute Coronary Syndromes (PL-ACS). Characteristics, treatments and outcomes of patients with acute coronary syndromes in Poland. Kardiol Pol. 2007; 65: 861-872.

17 Zembala M, Tajstra M, Zembala M, et al. Prospective randomised pilOt study evaLuating the safety and efficacy of hybrid revascularisation in MultI-vessel coronary artery DisEaSe (POLMIDES) – study design. Kardiol Pol. 2011; 69: 460-466.

18 Harskamp RE, Vassiliades TA, Mehta RH, et al. Comparative effectiveness of hybrid coronary revascularization vs coronary artery bypass grafting. J Am Coll Surg. 2015; 221: 326-334.

19 Peng Z, Pengyu Z, Yong S, et al. Hybrid coronary revascularization versus coronary artery bypass grafting for multivessel coronary artery disease: systematic review and meta-analysis. J Cardiothorac Surg. 2015; 10: 63.

20 McPhee PG, Winegard KJ, MacDonald MJ, et al. Importance of early cardiac rehabilitation on changes in exercise capacity: a retrospective pilot study. Appl Physiol Nutr Metab. 2015; 40, 12: 1314-1317.

21 Michta K, Pietrzyk E, Wożakowska-Kapłon A. Atrial fibrillation after coronary artery bypass graft. Kardiol Pol. 2013; 71: 1082-1086.

22 Archbold RA, Curzen NP. Off-pump coronary artery bypass graft surgery: the incidence of postoperative atrial fibrillation. Heart. 2003; 89, 10: 1134-1137.

23 Siebert J, Lewicki Ł, Młodnicki M, et al. Atrial fibrillation after corventional and off-pump coronary artery bypass grafting; two opposite trends in timing of atrial fibrillation occurrence? Med Sci Monit. 2003; 9, 3:137-141.

24 Misiołek H, Kucia H, Werner M, et al. Thoracotomy under epidural analgesia in a conscious patient. Case report. Anaesthesiol Intensive Ther. 2004; 2: 119-122.

25 Kucewicz E, Puzio J, Bojarski J, et al. Effects of on pump and off pump surgery on early results of coronary artery bypass grafting. Anaesthesiol Intensive Ther. 2006; 3: 140-143.

26 Shen S, He T, Chu J, et al. Uncontrolled hypertension and orthostatic hypotension in relation to standing balance in elderly hypertensive patients. Clin Interv Aging. 2015; 28; 10: 897-896.

27 Jones CD, Loehr L, Franceschini N, et al. Orthostatic hypotension as a risk factor for incident heart failure: the atherosclerosis risk in communities study. Hypertension. 2012; 59: 913-918.