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ARTYKUŁ ORYGINALNY / *ORIGINAL ARTICLE*

Ten-year experience of an invasive cardiology centre with out-of-hospital cardiac arrest patients admitted for urgent coronary angiography

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Abstract

Background and aim: The aim of the study was to evaluate survival and neurological function of out-of-hospital cardiac arrest (OHCA) patients admitted for urgent coronary angiography (UCA) with a view to percutaneous coronary intervention (PCI).

Methods: Hospital records of OHCA patients admitted to an invasive cardiology centre (providing 24 h a day/7 days a week service) in 2000–2010 were reviewed retrospectively, and similar data collected in 2011 were reviewed prospectively. Reports from the pre-hospital phase from emergency medical services (EMS) in Krakow were also analysed. Long-term follow-up data were collected by retrieving records from other hospitals (for patients transferred after UCA/PCI) and by phone calls to patients or their relatives.

Results: In 2000–2011, 405 OHCA patients were admitted for UCA/PCI. Most (78%) had ventricular fibrillation (VF) or ventricular tachycardia (VT) as the primary mechanism of cardiac arrest (asystole: 13%, pulseless electrical activity: 3%, unknown: 6%). The mean patient age was 61 (range 20–85) years, and 81% were males. On admission, about 70% of patients were unconscious and 11% were in cardiogenic shock. The mean resuscitation time (time to return of spontaneous circulation [ROSC]) was 26.7 (range 1–126) min. ST-T changes seen in an electrocardiogram recorded after ROSC included ST elevation and depression in 52% of cases, only ST depression in 21% of cases, only ST elevation in 17% of cases, unspecific changes (due to intraventricular conduction disturbances) in 7% of cases, negative T waves in 3% of cases, and no changes in 0.5% of cases. Coronary angiography revealed acute coronary occlusion in 48% of cases, critical coronary stenosis (> 90%) in 26% of cases, other significant coronary lesions (> 50% stenosis) in 15% of cases, and non-significant lesions in 11% of cases. An acute coronary syndrome (ACS) was diagnosed in 82% of patients (75% STEMI, 25% NSTEMI), and other cardiac cause (mostly ischaemic cardiomyopathy) was identified in 13% of patients. Among OHCA patients diagnosed with ACS, PCI was performed in 90% and additional 4% underwent coronary artery bypass grafting. Overall success rate of PCI, defined as TIMI 3 flow plus residual stenosis < 50% and resolution of ST elevation after PCI by > 30%, was 70%. Survival to hospital discharge in the entire group of OHCA patients was 63% and 30-day survival with good neurological outcomes (defined as Cerebral Performance Category 1 or 2) was 49%. Among patients who were initially unconscious, those figures were 52% and 33%, respectively. During long-term follow-up (up to 12 years), 49% of patients were alive and 42% had good neurological function (87% of those who survived). In multivariate analysis, independent predictors of survival with good neurological outcomes were preserved consciousness on admission, absence of shock, cardiac arrest witnessed by medical personnel, VF/VT as a primary mechanism of cardiac arrest, and preserved renal function. Successful PCI predicted survival until hospital discharge only when the neurological status of the patients was not taken into account.

Conclusions: The most important cause of OHCA is coronary artery disease, in particular ACS. UCA and PCI seem to be important elements of appropriate post-resuscitation care because such treatment could improve survival but it is still unclear whether PCI might influence neurological outcomes as well.

Key words: out-of-hospital cardiac arrest, coronary angiography, percutaneous coronary intervention, survival, neurological outcome

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INTRODUCTION

Cardiac arrest is a major cause of mortality in developed countries [1]. The incidence of out-of-hospital cardiac arrest (OHCA) in the European population has been estimated at about 40 per 100,000 per year [2]. Coronary artery disease is thought to be responsible for up to 80% of OHCA cases [3]. Survival after OHCA remains very low at about 10% [4]. Overall patient survival following cardiac arrest depends on all components of the chain of survival, including appropriate post-resuscitation care (Fig. 1) [5]. In addition to mild therapeutic hypothermia, an essential component of the latter is now early coronary angiography (CAG) and interventional treatment [6]. It has been suggested that urgent coronary intervention in unconscious patients after cardiac arrest may improve survival [7]. In the current European Society of Cardiology (ESC) guidelines, invasive CAG and interventional treatment are recommended in patients with ST segment elevation myocardial infarction (STEMI) complicated by cardiac arrest (class of recommendation I, level of evidence B), and such treatment should be considered in patients after cardiac arrest presenting without ST elevation but with suspected myocardial infarction (MI) as the cause of cardiac arrest (class of recommendation IIa, level of evidence B) (Fig. 1) [8].

The aim of this study was to evaluate treatment outcomes in OHCA patients with likely coronary aetiology of the event who were admitted for urgent invasive CAG. The primary endpoint was survival with good neurological outcome at discharge. Good neurological outcome was defined as survival until discharge with no or only mild neurological deficits (allowing independent functioning) — Cerebral Performance Category 1–2 [9]. A secondary endpoint was survival until discharge regardless of the neurological outcome (Table 1).

METHODS

We studied consecutive OHCA patients with likely cardiac aetiology admitted for urgent invasive CAG to the Centre of Invasive Cardiovascular Treatment (CILChSiN, *Centrum Interwencyjnego Leczenia Chorób Serca i Naczyń*). The decision to admit an OHCA patient for invasive CAG was made by a physician on duty in the cardiac catheterisation laboratory, and it was based on individual clinical judgment of the likelihood that cardiac arrest was due to an acute coronary syndrome (ACS).

Data on patients admitted following a cardiac arrest from January 2000 till August 2010 were collected retrospectively based on available medical records and digitally stored CAGs. In addition, when a patient was later transferred to another hospital in Krakow, respective medical records of these patients were retrieved from hospital archives to determine further clinical course, patient destination at final discharge, and neurological condition. Data regarding circumstances of cardiac arrest and details of resuscitation were obtained from emergency medical services (EMS) in Krakow. In addition, data regarding long-term survival of residents of the Malopolskie voivodship were obtained from the Universal Electronic System for Registration of the Population (PESEL, *Powszechny Elektroniczny System Ewidencji Ludności*) database. Since September 2010, all patient-related data were collected prospectively. Details regarding cardiac arrest were collected based on interviews with EMS team leaders involved in the resuscitation, EMS dispatchers, and patient family members. For the purpose of prospective data collection, we also developed a special post-cardiac arrest patient form intended to be filled by physicians on duty who admitted such patients for invasive CAG (Fig. 2).

During the next stage of the study (October 2011 till January 2012), we contacted patients or their families by phone to ascertain current neurological status of the patient and occurrence of long-term outcomes including reccurent cardiac arrest, cardiovascular death, MI, stroke, and implantation of an implantable cardioverter-defibrillator (ICD) for secondary prevention of sudden cardiac death (SCD).

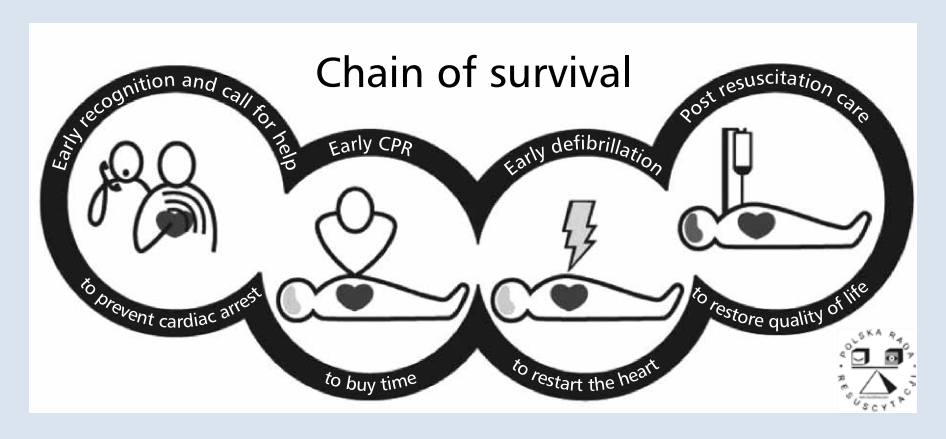

Figure 1. Chain of survival, CPR — cardiopulmonary resuscitation

Table 1. Cerebral Performance Category (CPC) scale

Category	Description
CPC 1	Good cerebral performance: conscious, alert, able to work, might have mild neurological or psychological deficit (mild dysphasia, mild hemiparesis or mild cranial nerve disturbances).
CPC 2	Moderate cerebral disability: conscious, sufficient cerebral function for independent activities of daily life (getting dressed, using public transport, preparing meals), able to work in sheltered environment. Hemiparesis, epilepsy, ataxia, dysarthria, dysphasia, and permanent memory or mental deficits may be present.
CPC 3	Severe cerebral disability: conscious but with varyingly limited ability to interact with environment, dependent on others for daily support because of impaired brain function (in long-term care facility or at home). Ranges from ambulatory patients but with severe memory deficits or dementia to those paralysed, bedridden and able to communicate with the eyes only (locked-in syndrome).
CPC 4	Coma or vegetative state: cerebral unresponsiveness, unawareness, without interaction with environment even if may show sleep/awake cycles and open eyes spontaneously; does not fulfil brain death criteria.
CPC 5	Brain death, apnoea, areflexia, electroencephalography silence.

Severity of coronary atherosclerosis was evaluated based on the number of vessels with significant lesions (> 50% stenosis) and additionally using the Syntax score [10]. Coronary angioplasty success was defined as TIMI 3 flow in the culprit artery following coronary intervention [11], less than 50% residual stenosis, and resolution of ST elevation (in STEMI patients) by at least 30% in an electrocardiogram (ECG) recorded immediately after the procedure.

The study was approved by the Bioethics Committee at the Jagiellonian University (approval No. KBET/210/B2010 of November 25, 2010).

Statistical analysis

Categorical variables were reported as numbers and percentages of items in each class. Quantitative variables were reported as arithmetic means, medians, and standard deviations. We then evaluated the effect of studied variables on the primary endpoint of the study. For categorical variables, rates of the primary endpoint for different variable categories were shown using contingency tables, and statistical significance of the differences was evaluated using the χ^2 test. Differences between mean values of quantitative variables in patients groups defined by the presence or absence of the primary endpoint were evaluated using the Student t test for normally distributed variables and the Mann-Whitney U test for non-normally distributed variables. Multivariate analysis was performed using the logistic regression method. Significance was set at the alpha level of 0.05. Statistical analyses were performed using the Statistica PL 10 software (Statsoft).

RESULTS

Overall, we studied 405 OHCA patients, including 340 patients identified retrospectively and 65 patients evaluated prospectively. The mean annual number of such patients admitted to CILChSiN was about 36 (Fig. 3).

Patients after cardiac arrest constituted only a small proportion (about 2%) of all acutely admitted patients. The mean age was 61 years, 81% of patients were men, and ventricular fibrillation (VF) or ventricular tachycardia (VT) was identified as the primary mechanism of cardiac arrest in 78% of patients. In 44% of patients, cardiac arrest was witnessed by healthcare personnel (which resulted in immediate initiation of advanced life support), and the mean time from cardiac arrest to the return of spontaneous circulation (ROSC) was 26.7 min. On admission to CILChSiN, two thirds of patients were unconscious, and 1 in 10 patients was in cardiogenic shock (Table 2).

ST segment changes seen in an ECG recorded after ROSC are shown in Figure 4. The most commonly identified changes were ST segment elevation or ST elevation and depression (Fig. 4).

CAG showed an acute vessel occlusion in 48% of patients, a critical stenosis (> 90%) in 26% of patients, and other significant coronary atherosclerotic lesions (50–90% stenosis or chronic occlusion) in 15% of patients. In only 11% of patients, no significant coronary lesions were found in CAG performed after cardiac arrest (Fig. 5).

Most (41%) patients were found to have single-vessel disease, and two- and three-vessel disease was identified in 33% and 26% of patients, respectively. Involvement of the left main (LM) coronary artery (either isolated or combined with other lesions) was found in 8.5% of patients. The infarct-related artery was most commonly the left anterior descending artery (in approx. 39% of cases), followed by the right coronary artery (approx. 26%), left circumflex artery (LCx) (approx. 12%), diagonal, marginal, or intermediate branch (overall 18% of cases), LM (3%), and a surgical graft (2%).

Significant coronary atherosclerotic lesions were found to be more common in older patients, those with a history of MI, chest pain before cardiac arrest, ST elevation in ECG recorded after ROSC, higher high-sensitivity troponin T levels

Invasive strategy after cardiac arrest

First name ..... Family name ..... Age .....

Date ..... and the time of cardiac arrest .....

Place of cardiac arrest: Home ☐ Public place ☐ During transport ☐ Primary care ☐ Other .....

Mechanism of cardiac arrest: VF/VT ☐ Asystole ☐ PEA ☐ No data ☐

Chest pain/pain equivalent before cardiac arrest: Yes ☐ No ☐ No data ☐

Cardiac arrest witnessed: Yes ☐ No ☐ No data ☐

Resuscitation initiated by witnesses: Yes ☐ No ☐ No data ☐

Time from cardiac arrest to ALS (initiation of resuscitation by the EMS team) ..... minutes No data ☐

Duration of ALS by the EMS team ..... minutes No data ☐

Only defibrillation: Yes ☐ No ☐

Number of defibrillations .....

Adrenalin dose ..... mg

Total time from cardiac arrest to ROSC ..... minutes No data ☐

Recurrent cardiac arrest after ROSC: Yes ☐ No ☐ ..... minutes

Shock (systolic blood pressure < 90 mm Hg or catecholamine infusion): Yes ☐ No ☐

Patient conscious ☐ Responsive to voice ☐ Purposeful movements ☐ Responsive to pain ☐ Not responsive ☐

Use of sedative agents/opioids/muscle relaxants: Yes ☐ No ☐ No data ☐ Seizures ☐

Resuscitation by: Krakow EMS ☐ Nowa Huta EMS ☐ Other .....

First name and surname of the EMS team leader .....

Contact phone of the EMS team leader .....

EMS data (to be filled in later)

First team on scene: With an EMS physician ☐ Only paramedics ☐ Reason for EMS call .....

Timing of EMS call ☐☐:☐☐ Timing of arrival on scene ☐☐:☐☐

Timing of initiation of ALS ☐☐:☐☐ Timing of ROSC ☐☐:☐☐

Patient transported directly by EMS ..... Transferred from another hospital .....

Figure 2. Cardiac arrest patient form; ALS — advanced life support; EMS — emergency medical services; ROSC — return of spontaneous circulation; VF/VT — ventricular fibrillation/ventricular tachycardia; PEA — pulseless electrical activity

on admission, and higher peak levels of all markers of myocardial necrosis (i.e., troponin I, troponin T, creatine kinase, and its MB isoenzyme) during hospitalisation. In contrast, significant coronary atherosclerotic lesions were found to be less common if left bundle branch block was identified in ECG recorded after ROSC (Table 3).

Multivariate analysis identified the following significant predictors of significant coronary atherosclerotic lesions in patients after cardiac arrest: a history of MI, chest pain before cardiac arrest, ST elevation in ECG recorded after ROSC, and older age (Table 4).

As the mere presence of significant coronary atherosclerotic lesions does not equate to the diagnosis of ACS, a similar multivariate analysis was performed to identify predictors of an acute vessel occlusion or a critical stenosis (> 90%). The only significant predictors of an acute vessel occlusion or a critical coronary stenosis were chest pain before cardiac arrest (relative risk [RR] 2.09, 95% confidence interval [CI] 1.37–3.19) and ST elevation in ECG recorded after ROSC (RR 1.56, 95% CI 1.02–2.38).

An ACS was the final diagnosis in 82% of patients (75% STEMI, 25% non-STEMI [NSTEMI]), other cardiac cause of cardiac arrest (most commonly ischaemic cardiomyopathy) was diagnosed in 13% of patients, and a non-cardiac or unknown cause was diagnosed in 5% of patients (Fig. 6).

Primary coronary intervention (PCI) was performed in 90% of patients with the diagnosis of ACS, and coronary artery bypass grafting was performed in additional 4% of patients. PCI was successful (TIMI 3 flow, resolution of ST segments changes and no significant residual stenosis) in

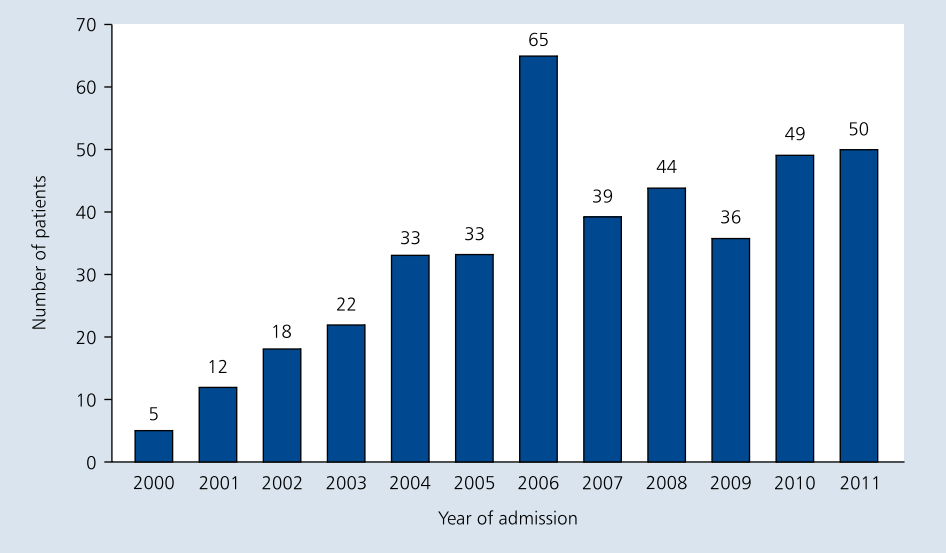

Figure 3. Number of post-cardiac arrest patients admitted to Centre of Invasive Cardiovascular Treatment (CILChSiN, *Centrum Interwencyjnego Leczenia Chorób Serca i Naczyń*) in 2001–2012

Table 2. Clinical data, circumstances of cardiac arrest, and patient status on admission

Age [years]	61 (20–85)
Men	81%
Previous MI	27%
Previous PCI or CABG	12%
Diabetes	19%
Hypertension	56%
Obesity	24%
Smoking	35%
Mechanism of CA:	
VF/VT	78%
Asystole	13%
PEA	3%
Unknown	6%
CA witnessed by medical personnel	44%
CA at home	36%
CA in a public place	20%
Defibrillation-only CPR	18%
BLS by witnesses	27%
Time to ALS [min]	8.69 (1.0–30.0)
Time to ROSC [min]	26.7 (1.0–126.0)
CS after ROSC	11%
CS during hospitalisation	29%
Patients unconscious on admission	70%

ALS — advanced life support; BLS — basic life support; CA — cardiac arrest; CABG — coronary artery bypass grafting; CPR — cardiopulmonary resuscitation; CS — cardiogenic shock; MI — myocardial infarction; PCI — percutaneous coronary intervention; PEA — pulseless electrical activity; ROSC — return of spontaneous circulation; VF — ventricular fibrillation; VT — ventricular tachycardia

70% of patients, and TIMI 3 flow was obtained in 76% of patients. Overall survival to hospital discharge was 63%, and survival with good neurological outcome at discharge was 49%. In the subset of patients who were unconscious on admission, these survival rates were 52% and 33%, respectively (Fig. 7).

Overall long-term survival (more than 10 years of follow-up of patients admitted in 2000) was 49%, and long-term survival in good neurological condition was 42% (87% among those who survived). Long-term mortality was higher among those discharged in poor neurological condition than those discharged in good condition (45% vs. 15%, $p = 0.0204$) (Fig. 8).

In addition, the estimated rates of major adverse cardiovascular events during long-term follow-up of patients after cardiac arrest were as follows: recurrent cardiac arrest: 11.9%, cardiovascular death: 7.5%, MI: 7%, stroke: 5.8%, and the overall rate of cardiac arrest, cardiovascular death, MI, and stroke was 20.4%. An ICD was implanted for secondary prevention of SCD in 22.7% of patients.

To evaluate the primary endpoint of the study, we assessed the effect of various clinical, ECG, angiographic, and laboratory variables on survival with good neurological outcome at discharge.

Variables that were associated with an increased likelihood of good neurological outcome included cardiac arrest mechanism amenable to defibrillation, cardiac arrest witnessed by healthcare personnel, immediate initiation of basic life support by witnesses of cardiac arrests, preserved consciousness and pupil reactions on admission, single-vessel disease, higher peak left ventricular ejection fraction, and successful coronary angioplasty. Variables that were associated

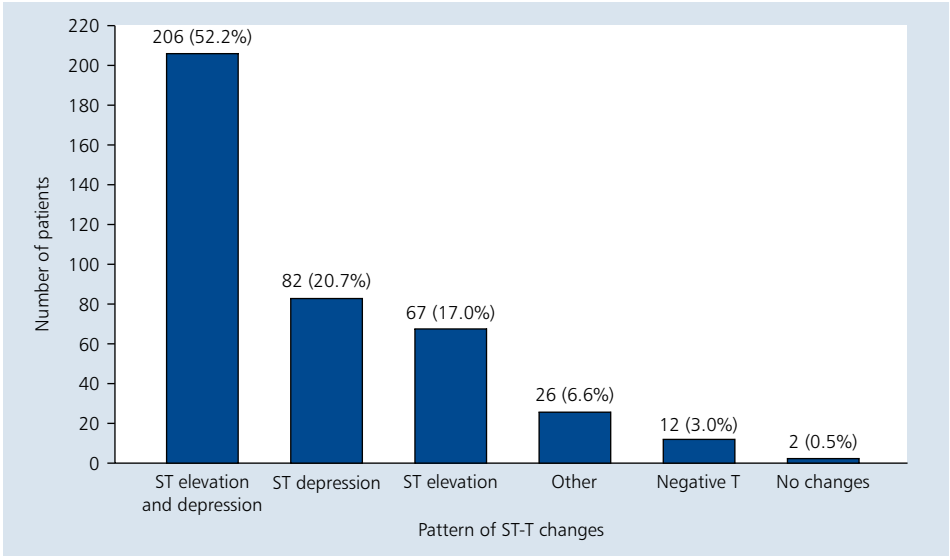

Figure 4. ST-T changes in electrocardiogram recorded after return of spontaneous circulation in post-cardiac arrest patients

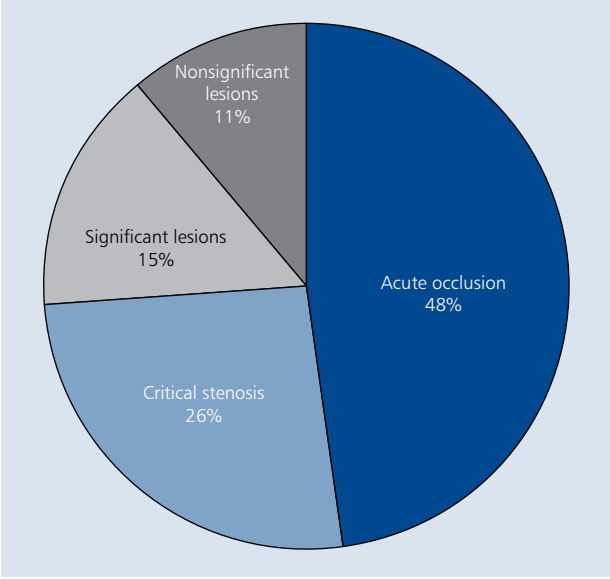

Figure 5. Severity of coronary atherosclerotic lesions in post-cardiac arrest patients

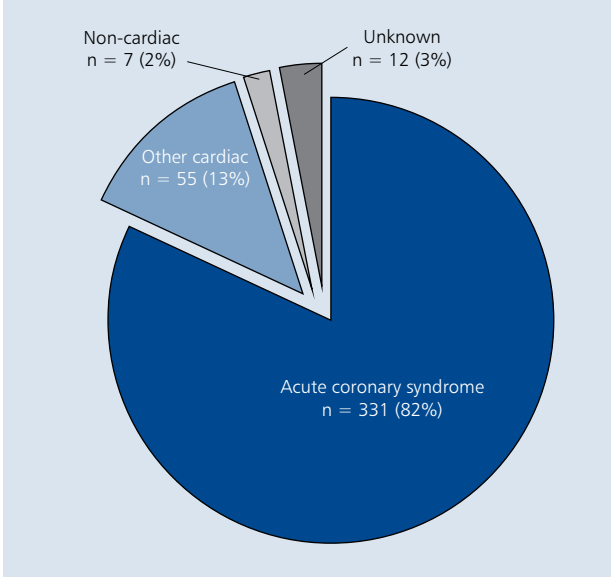

Figure 6. Final diagnosis of the cause of cardiac arrest (CA) in patients admitted for urgent coronary angiography after CA

with a reduced likelihood of good neurological outcome included longer time to EMS team arrival on scene, longer duration of resuscitation, longer time to ROSC, diabetes, higher blood glucose and lactate levels on admission, higher peak troponin level, leukocyte count, and body temperature, cardiogenic shock after ROSC or during hospitalisation, and development of renal failure or pneumonia (Table 5).

Multivariate analysis showed that independent predictors of good neurological outcome after cardiac arrest included preserved consciousness on admission, cardiac arrest mechanism amenable to defibrillation, cardiac arrest witnessed by healthcare personnel, absence of cardiogenic shock, and preserved renal function (glomerular filtration rate > 60 mL/min/1.73 m^2 as estimated using the Modification of Diet in Renal Disease [MDRD] formula) (Table 6).

A similar analysis was performed for the secondary endpoint of survival until hospital discharge regardless of the neurological outcome. Independent predictors of survival included preserved consciousness on admission, cardiac arrest mechanism amenable to defibrillation, successful coronary angioplasty, absence of cardiogenic shock, and preserved renal function (Table 7).

Table 3. Association between various clinical parameters and the presence of significant atherosclerotic lesions in coronary angiography in patients after cardiac arrest — univariate analysis

Parameter	Nonsignificant stenoses (n = 47)	Significant stenoses (n = 353)	P
Mean age [years]	54.8%	61.5%	0.000
Male gender	37 (78.7%)	289 (81.9%)	0.6
Hypertension	26 (56.5%)	196 (56.1%)	0.96
Diabetes	7 (15.2%)	69 (19.8%)	0.45
Hypercholesterolaemia	23 (50%)	201 (57.9%)	0.3
Obesity	10 (27%)	68 (23.8%)	0.67
Smoking	14 (70%)	113 (64.2%)	0.6
Coronary artery disease	15 (32.6%)	155 (44.2%)	0.14
Previous MI	7 (15.2%)	100 (28.5%)	0.04
Revascularisation	3 (6.7%)	43 (12.3%)	0.27
Stroke	3 (6.4%)	22 (6.3%)	0.98
Peripheral arterial disease	3 (6.7%)	36 (10.8%)	0.39
VF/VT	34 (77.3%)	281 (83.8%)	0.27
Chest pain	11 (31.4%)	202 (69.7%)	0.000
ST-T changes:			
ST elevation	16 (34%)	255 (72.2%)	0.000
ST depression	17 (37.8%)	63 (18.2%)	0.08
Negative T waves	1 (2.2%)	11 (3.2%)	0.8
Unspecific changes	10 (22.2%)	11 (3.2%)	0.17
QRS changes:			
Normal pattern	27 (60%)	230 (68%)	0.39
LBBB	9 (20%)	23 (6.8%)	0.014
RBBB	4 (8.9%)	37 (10.9%)	0.89
Unspecific	5 (11.1%)	48 (14.2%)	0.84
Biomarkers on admission, mean:			
Tn [ng/mL]	2.70	5.18	0.27
hsTnT [ng/mL]	0.1634	0.5564	0.032
CK-MB [U/L]	70.4	77.8	0.58
CK [U/L]	544.9	646.4	0.66
Peak biomarkers, mean:			
TnI [ng/mL]	31.70	73.24	0.004
hsTnT [ng/mL]	0.071	6.784	0.017
CK-MB [U/L]	169.7	363.3	0.001
CK [U/L]	2788.9	4841.1	0.21

CK — creatine kinase; CK-MB — creatine kinase isoenzyme MB; hsTnT — high-sensitivity troponin T; LBBB — left bundle branch block; RBBB — right bundle branch block; MI — myocardial infarction; Tn — troponin; VF — ventricular fibrillation; VT — ventricular tachycardia

DISCUSSION

Our findings confirm that coronary artery disease is the most common cause of cardiac arrest among OHCA patients who are admitted for urgent CAG. An acute vessel occlusion was found in nearly half of patients, and a critical stenosis in further 25% of patients. These results are very similar to those reported by Spaulding et al. [12] who evaluated a population of OHCA patients without a clear non-cardiac cause of cardiac arrest and found an acute occlusion of an epicardial coronary artery in 47% of patients, and significant non-occlusive coronary artery disease in another 24% of patients. Other authors reported somewhat lower rates of coronary artery disease in populations of OHCA patients. Among patients after OHCA admitted for routine CAG, Anyfantakis et al. [13] found coronary artery occlusion in only about 17% of patients, and other significant atherosclerotic coronary lesions in about 47% of patients. MI was diagnosed in only 38% of cases as for that diagnosis the authors required the presence

Table 4. Independent predictors of significant coronary atherosclerotic lesions in patients after cardiac arrest — univariate analysis

Variable	Category	N	RR	95% CI	P
History of MI	Yes	109	1.84	1.08-3.14	0.0241
	No	293	1.00	–	–
Chest pain	Yes	214	2.15	1.42–3.26	0.0003
	No	115	1.00	–	–
ST elevation	Yes	273	2.11	1.4–3.19	0.0003
	No	132	1.00	–	–
Age (per year)	–	405	1.04	1.01–1.07	0.0101

CI — confidence interval; MI — myocardial infarction; N — number of patients; RR — relative risk

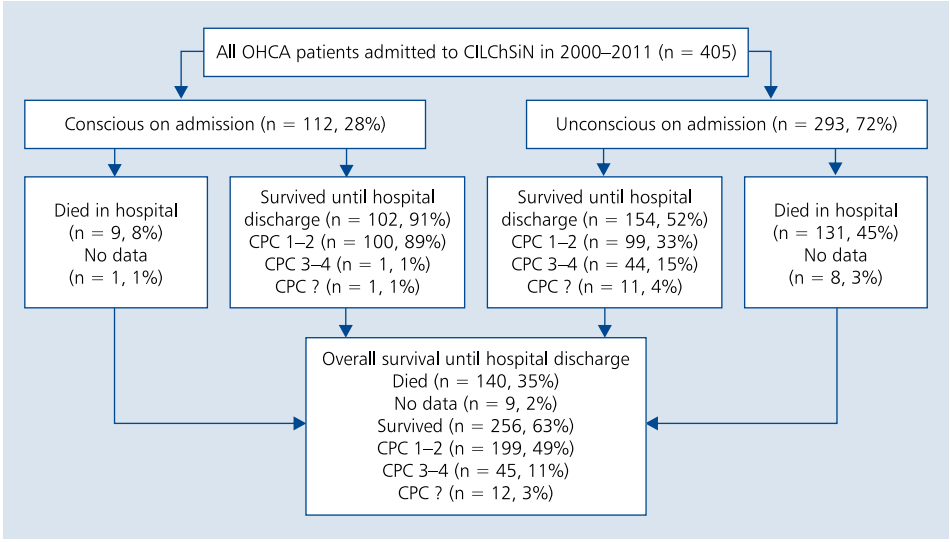

Figure 7. Survival and neurological outcomes in post-cardiac arrest patients at hospital discharge; CILChSiN — Centre of Invasive Cardiovascular Treatment (*Centrum Interwencyjnego Leczenia Chorób Serca i Naczyń*, John Paul II Hospital, Krakow, Poland; CPC — Cerebral Performance Category, score 1–2 indicates good neurological outcomes; OHCA — out-of-hospital cardiac arrest

of not only a significant but also unstable atherosclerotic lesion. Similarly, Sideris et al. [14] reported that the rate of ACS among patients with OHCA was only about 36%. Thus, it seems that the identification rates of significant and critical coronary lesions and the rates of ACS diagnosed as the cause of cardiac arrest depend mainly on the selected patient admission criteria and the definition of ACS in post-OHCA patients referred for urgent CAG, ranging widely from 30% to 80%.

The rationale for admitting OHCA patients for invasive CAG is a suspicion of significant coronary atherosclerotic lesions which might be treated invasively. For physicians on duty in cardiac catheterisation laboratories, the major challenge in the everyday clinical practice is thus proper identification of those OHCA patients who require urgent CAG. Our study showed that only older age, a history of MI, the presence of chest pain before cardiac arrest, and ST segment elevation identified in the ECG recorded after ROSC were independent predictors of significant coronary atherosclerotic lesions. The above cited authors found that among numerous potential factors, only chest pain and ST elevation [12] or ST elevation and smoking [13] were independent predictors of significant coronary atherosclerotic lesions and the diagnosis of MI in their studies. Thus, the presence of these characteristics might argue for admitting the OHCA patient for urgent CAG.

The major goal of performing coronary angioplasty in OHCA patients is to improve their prognosis. In patients after cardiac arrest, however, improving higher neurological functions seems to be a more important goal that just patient survival, and thus the ultimate goal is survival with good neurological outcome. In our study, survival with good neurological outcome was more frequent among those patients who underwent successful coronary angioplasty compared to those without angioplasty success (58% vs. 42%, p = 0.029), but in multivariate analysis, successful angioplasty was not an independent predictor of good neurological outcome. In contrast, significant independent predictors of good neurological outcome were preserved consciousness on admission, cardiac arrest witnessed by healthcare personnel, cardiac

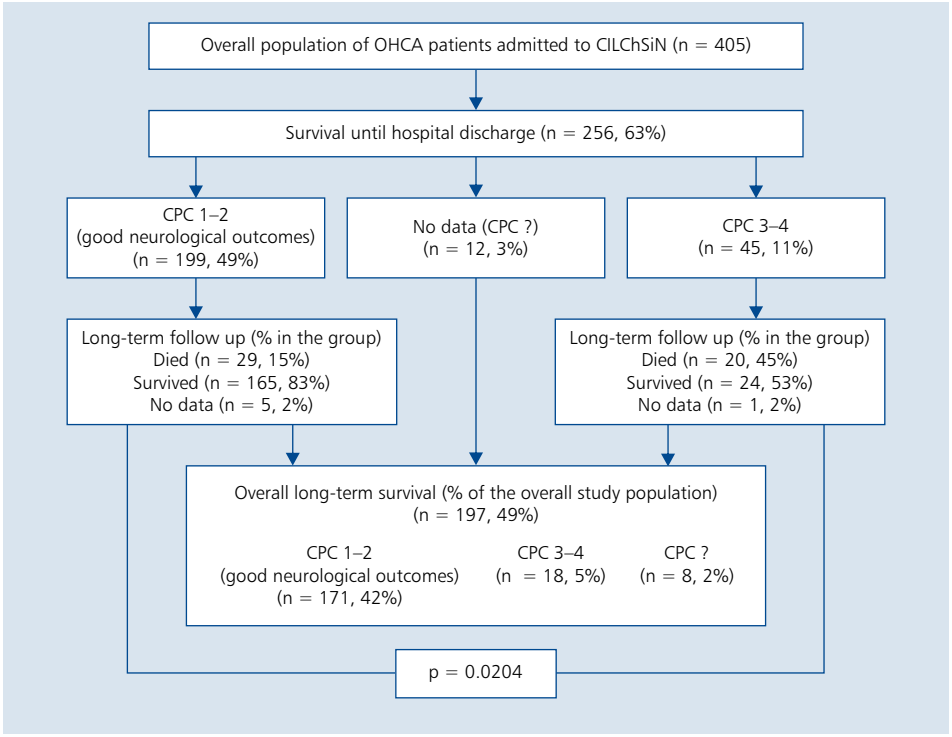

Figure 8. Long-term survival and neurological outcomes in post-cardiac arrest patients; CILChSiN — Centre of Invasive Cardiovascular Treatment (*Centrum Interwencyjnego Leczenia Chorób Serca i Naczyń*, John Paul II Hospital, Krakow, Poland; CPC — Cerebral Performance Category, score 1–2 indicates good neurological outcomes; OHCA — out-of-hospital cardiac arrest

arrest mechanism amenable to defibrillation, absence of cardiogenic shock, and preserved renal function. However, when we analysed the effect of numerous variables on survival regardless of neurological outcome, successful coronary angioplasty was shown to increase the likelihood of survival until hospital discharge (RR 3.0, 95% CI 1.38–6.58, p = 0.0057). It may be thus speculated that prehospital factors such as immediate initiation of chest compression and cardiac arrest mechanism amenable to defibrillation may be of prime importance for brain function following ROSC. Most data available in the literature (observational studies, retrospective analyses, and patient series) indicate improved survival of cardiac arrest patients in whom successful coronary angioplasty was performed regardless of the changes seen in ECG [15–17]. Only few authors were unable to show survival improvement associated with urgent coronary angioplasty in patients after cardiac arrest. Despite that, most of these authors recommended an invasive strategy in patients after cardiac arrest in whom MI is suspected [18, 19]. With current knowledge, it cannot be unequivocally determined whether PCI in patients after cardiac arrest is an independent factor that improves survival and neurological outcomes. It would be necessary but ethically questionable to perform a randomised study in which post-cardiac arrest patients with likely cardiac aetiology of the event would be assigned to early interventional or medical management. It should also be noted that although the ESC guidelines recommend immediate invasive CAG in post-cardiac arrest patients with ST segment elevation (class of recommendation I, level of evidence B) and only suggest such an approach in patients without ST elevation in whom ACS is suspected (class of recommendation IIa, level of evidence B), our study did not show any difference in outcomes, including both survival and neurological condition, between STEMI and NSTEMI patients.

Limitations of the study

Major limitations of our study include its retrospective and observational nature. The study was largely based on information retrieved from patient medical records, without any possibility of direct data verification. Regarding the prehospital period, data were often lacking on the circumstances of cardiac arrest and undertaken resuscitation procedures. In the prospectively evaluated patient subset, although information on the duration of resuscitation was collected directly from the EMS team involved, the obtained data were often subjective and not based on any objective measurements. Another obvious weakness of the study has been the fact that patients were selected for urgent invasive CAG by a physician on duty in the cardiac catheterisation laboratory. For obvious reasons, no randomisation was possible in these circumstances. Also, no formal criteria were used regarding which post-cardiac arrest patients should be admitted and which should not. The

Table 5. Relation between various parameters and good neurological outcomes in patients after cardiac arrest — univariate analysis

Variable	Category	N	RR	95% CI	P
Age	–	405	0.961	0.944–0.979	0.0000
Gender	Men	329	1.0	–	–
	Women	76	0.799	0.481–1.328	0.3864
Diabetes	No	321	1.0	–	–
	Yes	78	0.533	0.321–0.885	0.0151
Previous MI	No	293	1.0	–	–
	Yes	109	0.768	0.492–1.199	0.2455
Previous revascularisation	No	352	1.0	–	–
	Yes	47	0.790	0.424–1.475	0.4600
Mechanism of cardiac arrest	Non-DEF	66	1.0	–	–
	DEF	316	6.684	3.423–13.049	0.0000
Place of cardiac arrest	Home	131	1.0	–	–
	PUB	74	1.317	0.713–2.432	0.3776
	MED	162	6.199	3.678–10.447	0.0000
Life support by cardiac arrest witnesses	No	41	1.0	–	–
	BLS	111	3.465	1.514–7.926	0.0003
	ALS	165	11.564	5.096–26.245	0.0000
Time to EMS arrival at scene [min]	–	310	0.882	0.841–0.926	0.0000
Duration of ALS [min]	–		0.957	0.938–0.976	0.0000
Time from cardiac arrest to ROSC [min]	–	198	0.956	0.938–0.975	0.0000
State of consciousness on admission	Unconscious	293	1.0	–	–
	Conscious	112	17.677	8.820–35.427	0.0000
Glasgow coma scale	3	129	1.0	–	–
	4–7	61	5.800	2.812–11.963	0.0000
	8–14	27	46.000	12.43–170.16	0.0000
	15	59	171.000	38.13–766.82	0.0000
Pupil reactions	No	96	1.0	–	–
	Yes	236	10.5444	5.648–19.686	0.0000
Cause of cardiac arrest	Non-cardiac	19	1.0	–	–
	Non-ACS	55	1.999	0.649–6.154	0.2261
	NSTEMI	88	1.818	0.622–5.315	0.2739
	STEMI	243	2.466	0.892–6.817	0.0818
n-vessel disease (n-VD)	0-VD	43	1.0	–	–
	1-VD [237]	145	1.915	1.344–2.728	0.0003
	2-VD [238]	118	0.836	0.428–1.039	0.3452
	3-VD [239]	92	0.749	0.370–0.958	0.1744
Syntax score	–	372	0.986	0.966–1.007	0.1836
Maximum LVEF [%]	–	326	1.059	1.040–1.079	0.0000
Left bundle branch block	No	255	1.0	–	–
	Yes	32	0.631	0.292–1.362	0.2406
PCI success	No	72	1.0	–	–
	Yes	156	2.307	1.386–3.841	0.0013
Glycaemia	–		0.908	0.871–0.946	0.0000
Lactates	–		0.729	0.641–0.829	0.0000
Peak troponin I [ng/mL]	–		0.997	0.994–0.999	0.0181

→

Table 5. (cont.) Relation between various parameters and good neurological outcomes in patients after cardiac arrest — univariate analysis

Variable	Category	N	RR	95% CI	P
Duration of PCI [min]	–		0.991	0.979–1.004	0.1601
Peak leukocyte count [× $10^3/\mu L$]	–		0.944	0.910–0.979	0.0020
Body temperature on admission	–		1.073	0.812–1.418	0.6190
Maximum body temperature	–		0.465	0.385–0.604	0.0000
Shock after ROSC	No	361	1.0	–	–
	Yes	44	0.151	0.065–0.349	0.0000
Shock during hospitalisation	No	280	1.0	–	–
	Yes	125	0.216	0.134–0.347	0.0000
Shock overall	No	240	1.0	–	–
	Yes	164	0.108	0.067–0.173	0.0000
Pneumonia	No	255	1.0	–	–
	Yes	126	0.340	0.216–0.534	0.0000
Renal failure (GFR < 60 mL/min [MDRD formula])	No	177	1.0	–	–
	Yes	199	0.117	0.072–0.189	0.0000
GFR [mL/min]	< 15	20	1.0	–	–
	15–30	42	6.7398	0.799–56.878	0.0794
	30–60	133	10.5269	1.355–81.792	0.0246
	> 60	155	75.3216	9.605–590.633	0.0000
Time from cardiac arrest to PCI [h]	–	205	0.999	0.998–1.001	0.2440

ACS — acute coronary syndrome; ALS — advanced life support; BLS — basic life support; CI — confidence interval; DEF — amenable to defibrillation; EMS — emergency medical services; GFR — glomerular filtration rate; LVEF — left ventricular ejection fraction; MED — witnessed by medical personnel; MDRD — Modification of Diet in Renal Disease; MI — myocardial infarction; N — number of patients; non-ACS — cardiac but not ACS; non-DEF — not amenable to defibrillation; NSTEMI — non-ST elevation myocardial infarction; PCI — percutaneous coronary intervention; PUB — public place; ROSC — return of spontaneous circulation; RR — relative risk; STEMI — ST elevation myocardial infarction

Table 6. Independent predictors of good neurological outcomes after cardiac arrest — multivariate analysis

Variable	Category	N	RR	95% CI	P
State of consciousness	Unconscious	293	1.0	–	–
	Conscious	112	3.260	1.404–7.572	0.0060
Mechanism of cardiac arrest	Non-DEF	66	1.0	–	–
	DEF	316	2.457	1.172–5.153	0.0173
Place of cardiac arrest	Non-MED	205	1.0	–	–
	MED	162	2.166	1.207–3.884	0.0095
Shock	No	240	1.0	–	–
	Yes	164	0.453	0.255–0.806	0.0071
Renal failure	No	177	1.0	–	–
	Yes	199	0.403	0.234–0.692	0.0010

CI — confidence interval; DEF — amenable to defibrillation; MED — witnessed by medical personnel; N — number of patients; RR — relative risk

decision whether to admit was solely at the discretion of the involved physician and depended on his or her judgment of the likelihood that cardiac arrest was due to a cardiac cause. Also of note, cardiac arrest was witnessed by healthcare personnel in as many as 44% of patients. Such a high proportion of medically witnessed cardiac arrests, i.e. occurring in circumstances favouring immediate resuscitation efforts, was due to the fact that very often the EMS team was dispatched to a patient with chest pain, and cardiac arrest occurred after the EMS team arrived on scene or during patient transport to the hospital. This has undoubtedly affected our results as immediate resuscitation is a known factor favouring good

Table 7. Independent predictors of survival until hospital discharge in patients after cardiac arrest regardless of their neurological status — multivariate analysis

Variable	Category	N	RR	95% CI	P
State of consciousness	Unconscious	293	1.0	–	–
	Conscious	112	6.910	2.409–19.817	0.0003
Mechanism of cardiac arrest	Non-DEF	66	1.0	–	–
	DEF	316	4.287	1.828–10.054	0.0008
PCI success	No	72	1.0	–	–
	Yes	156	3.011	1.378–6.580	0.0057
Shock	No	240	1.0	–	–
	Yes	164	0.335	0.153–0.732	0.0061
Renal failure	No	177	1.0	–	–
	Yes	199	0.209	0.092–0.475	0.0002

CI — confidence interval; DEF — amenable to defibrillation; N — number of patients; PCI — percutaneous coronary intervention; RR — relative risk

outcomes, and at the same time it makes it more difficult to generalise our findings to the whole population of OHCA patients. It should also be noted that the studied OHCA patients were not subjected to mild therapeutic hypothermia (except for few patients near the end of the study period) which was introduced in CILChSiN since September 2011, and is an intervention shown in randomised studies to improve neurological function in post-cardiac arrest patients.

CONCLUSIONS

1. Patients with cardiac arrest preceded by chest pain, with a history of MI, with ST segment elevation, who are in old age, or with other clinical data suggesting ACS should be transferred directly to cardiac catheterisation laboratories.
2. Successful coronary angioplasty in patients after cardiac arrest increases their likelihood to survive.
3. Successful coronary angioplasty in patients after cardiac arrest does not predict good neurological outcomes at hospital discharge.

Conflict of interest: *none declared*

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Wyniki leczenia inwazyjnego u pacjentów po nagłym zatrzymaniu krążenia: 10 lat doświadczeń centrum kardiologii interwencyjnej

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Streszczenie

Wstęp i cel: Celem pracy była ocena wyników leczenia interwencyjnego pacjentów po nagłym zatrzymaniu krążenia (NZK) pozaszpitalnym o prawdopodobnie wieńcowej etiologii, przyjmowanych do pilnej diagnostyki inwazyjnej naczyń wieńcowych.

Metody: Retrospektywną (2000–2010) i prospektywną (2010–2011) analizą objęto dane medyczne chorych po NZK pozaszpitalnym przyjmowanych do centrum kardiologii interwencyjnej. Chorzy stanowiący populację badaną nie byli (z wyjątkiem kilku pacjentów pod koniec okresu obserwacji) poddawani łagodnej hipotermii terapeutycznej, która została wprowadzona w centrum kardiologii inwazyjnej dopiero od 1.09.2011 r. Analizie poddano okoliczności NZK i przebieg resuscytacji, dane demograficzne oraz przeszłość chorobową pacjentów, zapis EKG po przywróceniu tętna (ROSC), wyniki koronarografii oraz angioplastyki, wyniki badania echokardiograficznego i EKG po interwencji wieńcowej, przebieg i komplikacje występujące w trakcie hospitalizacji oraz przeżycie i stan neurologiczny w momencie wypisu ze szpitala, a także w obserwacji odległej.

Wyniki: W analizowanym okresie przyjęto 405 chorych po NZK, 340 w grupie retrospektywnej i 65 w grupie prospektywnej. Średni wiek pacjentów wyniósł 61 lat. 81% stanowili mężczyźni, u 78% stwierdzono migotanie komór lub częstoskurcz komorowy jako mechanizm NZK, 70% chorych było nieprzytomnych, a u 11% zaobserwowano wstrząs kardiogenny w chwili przyjęcia. Średni czas od NZK do ROSC wyniósł 26,7 min. W koronarografii u 48% osób wstępowała świeża okluzja tętnicy wieńcowej, a u 26% pacjentów stwierdzano zwężenia krytyczne. Ostatecznie ostry zespół wieńcowy (OZW) jako przyczynę NZK rozpoznano u 82% chorych (STEMI 75%, NSTEMI 25%), drugą najczęstszą przyczyną była kardiomiopatia niedokrwienna. Angioplastykę wieńcową wykonano u 90% chorych z OZW, a pomostownie aortalno-wieńcowe u 4% osób. Angioplastyka zakończyła się sukcesem u 70% pacjentów. Przeżycie do wypisu ze szpitala w całej grupie wyniosło 63%, a przeżycie w korzystnym stanie neurologicznym odnotowano u 49% pacjentów. W grupie chorych wyjściowo nieprzytomnych przeżycie i dobry stan neurologiczny zaobserwowano odpowiednio u 52% i 33% osób. W trakcie obserwacji odległej (do 12 lat po NZK) 49% pacjentów przeżyło, a 42% było w dobrym stanie neurologicznym (87% chorych, którzy przeżyli). Niezależnymi czynnikami decydującymi o przeżyciu w dobrym stanie neurologicznym były: zachowany stan przytomności w chwili przyjęcia, mechanizm defibrylacyjny NZK, zatrzymanie krążenia w obecności personelu medycznego, brak wstrząsu kardiogennego i zachowana funkcja nerek. Skuteczna angioplastyka wieńcowa wiązała się z poprawą przeżycia do wypisu ze szpitala, jeżeli nie uwzględniano stanu neurologicznego chorych.

Wnioski: Najważniejszą przyczyną pozaszpitalnego NZK jest choroba wieńcowa, a zwłaszcza ostre zespoły wieńcowe. Koronarografia i angioplastyka wieńcowa są ważnymi elementami właściwej opieki poresuscytacyjnej, ponieważ mogą poprawiać przeżywalność chorych po NZK, choć ich wpływ na osiągany stan neurologiczny pozostaje niejasny.

Słowa kluczowe: nagłe zatrzymanie krążenia, koronarografia, angioplastyka wieńcowa, przeżycie, rokowanie neurologiczne

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