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Clinical predictors of outcome in survivors of out-of-hospital cardiac arrest treated with hypothermia

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ABSTRACT

Background: Out-of-hospital cardiac arrest (OHCA) is a leading cause of death and severe neurological disability. The objective of this study was to identify clinical predictors of early neurological outcome in survivors of OHCA managed according to recent recommendations for OHCA care.

Methods: Data from survivors of OHCA, admitted to a tertiary cardiac intensive care unit and treated with hypothermia in a 22 months period ($n = 46$, age 60 ± 13 years, 74% males) were retrospectively evaluated. At 1-month follow-up, patients were classified according to the best achieved Glasgow–Pittsburgh cerebral performance categories (CPC 1–5) and factors affecting the outcome were analysed.

Results: At 1-month follow-up, 23 patients (50%) had favourable outcome (CPC 1–2), while 23 patients (50%) had poor outcome (CPC 3–5), including 19 with in-hospital death (41% of total). Patients with good outcome were younger (55 ± 13 years vs. 66 ± 10 years; $P = 0.003$), had more often myocardial infarction as the cause of arrest (63% vs. 30%; $P = 0.018$) and ventricular fibrillation/tachycardia as an initial rhythm (78% vs. 39%; $P = 0.007$). Both groups differed by lactate level on admission (4.0 ± 4.6 vs. 7.3 ± 4.1 mmol/l, $P = 0.02$), after 12 h (2.5 ± 1.1 vs. 4.3 ± 3.2 mmol/l, $P = 0.04$) and after 24 h (1.9 ± 1.2 vs. 3.2 ± 1.9 mmol/l, $P = 0.04$). Logistic regression revealed the following independent outcome predictors: age, acute myocardial infarction and admission lactate level.

Conclusion: Favourable outcome was observed in a half of OHCA survivors. Young age, acute myocardial infarction as underlying aetiology of cardiac arrest, and low lactate level on admission were the best predictors of favourable outcome.

1. Introduction

Sudden cardiac arrest is the leading cause of death in industrialized countries [1,2]. Although recent data suggest decreasing incidence of out-of-hospital cardiac arrest (OHCA), prognosis remains very dubious. Survival rates are variable and depend not only on pre-hospital but also on post-resuscitation in-hospital care [3,4]. Previous studies demonstrated significant institutional and regional differences in survival after OHCA [5,6]. Over the past-half century, many interventions improved the rate of restoration of spontaneous circulation (ROSC) but without impacting long-term survival [3]. During this period, major indicators for increased survival rate have not changed: younger age, VF/VT as initial rhythm, witnessed cardiac arrest, bystander cardiopulmonary resuscitation (CPR), and time elapsed to ROSC [7–9]. During the past few years, new pre-hospital and in-hospital therapeutic approaches have been introduced to improve outcome. These

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include provision of phone-guided CPR guidance by emergency line dispatcher, early induction of mild therapeutic hypothermia, urgent percutaneous coronary intervention in victims of OHCA due to acute myocardial infarction with ST elevations, and implantation of cardioverter-defibrillators before hospital discharge [10–12]. However, the prediction of the neurologic outcome with use of these novel procedures is not well defined. As hypothermia and accompanying sedation affects traditional indicators of preserved brain function, like level of consciousness or brainstem reflexes, it is important to identify early predictors of neurological outcome even during hypothermia treatment. The objective of this study was to evaluate the predictors of outcome in adult OHCA survivors admitted to a tertiary cardiac intensive care unit (ICU) with implemented recent recommendations for OHCA care.

2. Methods

2.1. *Patients*

In this retrospective cohort study, we analysed consecutive comatose adult patients with OHCA and ROSC (using the Utstein style definition) who were treated with therapeutic hypothermia [13]. These patients were admitted to cardiac ICU at Institute for Clinical and Experimental Medicine (IKEM) between January 2007 and October 2008. In all patients, standard medical management including invasive arterial pressure monitoring, close blood glucose control (insulin infusion to reach goal plasma glucose level of 6–10 mmol/l), and controlled mechanical ventilation with maintenance were provided in accordance with standard recommendations [3]. In order to maintain mean arterial pressure $\geq$65 mmHg and adequate tissue perfusion, hemodynamic support with noradrenaline (norepinephrine) and/or dobutamine was necessary in some patients. Immediate therapeutic hypothermia at admission using a cooling device (Blanketrol® II Hyper-Hypothermia System) alone or combined with initial ice-cold saline infusion (10 ml/kg) and ice packs on the patient's axilla and groin were deployed. The target core body temperature was 33 °C, measured by temperature-sensing thermistor urinary bladder catheter and maintained for 12–24 h. Re-warming was active and performed with a Blanketrol device. Rebound hyperpyrexia has been defined as at least two temperature readings above 37.5 °C during first 5 h after cooling cessation and achievement of normothermia. Patients with signs of acute infection (2 patients, 5%) or those who died during hypothermia (3 patients, 7%) were excluded and the remaining 41 patients were included in the sub-analysis of rebound hyperpyrexia. Sedation drug propofol and muscular relaxant pancuronium or pipecuronium were titrated to suppress shivering. All patients underwent an echocardiography evaluation. Urgent coronary artery catheterization in patients presenting with acute STEMI and direct percutaneous coronary intervention, if indicated were performed.

2.2. *Organization of regional emergency medical system (EMS) care for OHCA*

The city of Prague has a population of 1,226,697 inhabitants and covers an area of 496 km^2. Out-of-hospital care in Prague is provided by two types of mobile ambulances: rapid response units with a physician and advanced life support (ALS) units (ambulance vehicles comprising of a paramedic and a driver/rescue person). Emergency calls from the entire area of Prague are accepted continuously at a toll-free number and managed by a Medical Operation Centre handling over 255,000 emergency calls per year. All operators are qualified to guide cardiopulmonary resuscitation. Emergency crews handle approximately 500 adult OHCAs per year. Patient's clinical data, including suspected time of arrest, whether the arrest was witnessed, any pre-arrival resuscitation attempts and therapy provided by emergency medical service, and complications during transport to hospital are recorded by EMS personnel and were used as a source document. IKEM is a governmental tertiary health care facility specialized in advanced cardiovascular care and organ transplantation. The Heart Centre at IKEM provides round o'clock direct PCI service for acute STEMI with a volume of 300 direct PCI's per year. The Cardiac ICU at IKEM has 18 beds, taking care of an average of 1300 patients per year. Data were collected from EMS patient sheets, in-hospital patient records and final medical records if the patient was transferred. Time of onset of cardiac arrest was estimated from information provided by eye-witnesses.

2.3. *Study endpoint*

The primary endpoint was survival with favourable neurological outcome at 1-month follow-up. Neurological state was classified according to the best-achieved Glasgow–Pittsburgh cerebral performance categories (CPC 1: no or mild neurological disability; CPC 2: moderate neurological disability; CPC 3: severe neurological disability; CPC 4: coma, vegetative state; CPC 5: death, brain death). The favourable outcome was defined as CPC 1 or CPC 2.

2.4. *Statistical analysis*

Statistics were performed with SPSS statistical software (SPSS Inc, Chicago, IL, USA, 17.0). Continuous data are shown as mean$\pm$standard deviation, or as median with inter-quartile range (IQR) and compared by use of a two-tailed *t*-test, or if not normally distributed with the Mann–Whitney test. Categorical data are presented as absolute or relative frequencies and are analysed by the Pearson χ^2 test or Fisher's exact test in the presence of small numbers. A P value <0.05 was considered significant. Lactate clearance was calculated as the difference from baseline to 24 h after admission divided by the baseline value and multiplied by 100. To identify a parsimonious set of variables predicting favourable (CPC 1–2) or bad outcome (CPC 3–5), a multivariate logistic regression analysis with backward elimination based on likelihood if ratios (probability for removal $P>0.10$) was used. Characteristics significantly associated with poor outcome and/or from a clinical point of view may have influence outcome were included (listed bellow and marked by asterisks in Tables 1 and 2). Goodness-of-fit was tested with Hosmer–Lemeshow test.

Table 1 – Basic characteristics of the cohort.

	All patients (N = 46)	Outcome		P-value
		Good (CPC 1–2) (N = 23)	Poor (CPC 3–5), (N = 23)	
Male gender	34 (74%)	20 (87%)	14 (61%)	0.09
Mean age* (years)	60.2±12.7	54.8±12.4	65.6±10.3	0.003
History				
Hypertension	24 (54%)	12 (52%)	15 (65%)	0.2
Diabetes	12 (26%)	4 (17%)	8 (35%)	0.3
Coronary artery disease	9 (20%)	2 (10%)	10 (44%)	0.1
Smoking	15 (33%)	9 (39%)	6 (26%)	0.5
Medication				
Beta blocker	13 (28%)	3 (13%)	12 (52%)	0.02
Ca-channel blocker	5 (11%)	3 (13%)	3 (13%)	0.7
ACE inhibitor or ARB	(39%)	7 (30%)	11 (48%)	0.2
Statin	9 (20%)	2 (9%)	6 (26%)	0.3
Left ventricular ejection fraction (%)	31±13	31±14	31±13	0.9
Underlying aetiology				
Coronary artery disease	31 (67%)	17 (74%)	14 (61%)	0.3
Dilated cardiomyopathy	5 (11%)	3 (13%)	2 (9%)	–
Other	10 (22%)	3 (17%)	7 (30%)	–
Respiratory failure for COPD	2 (4%)	1 (4%)	2 (9%)	–
Idiopathic VF	4 (8%)	1 (4%)	2 (9%)	–
Undetermined	4 (8%)	1 (4%)	3 (13%)	–
Acute myocardial infarction*	22 (48%)	15 (65%)	7 (30%)	0.02
STEMI	16 (35%)	11 (48%)	5 (22%)	0.16
VF/VT*	27 (59%)	18 (78%)	9 (39%)	0.007
Witnessed cardiac arrest	39 (85%)	20 (87%)	19 (83%)	0.7
Bystander basic life support	29 (63%)	17 (74%)	12 (52%)	0.2
Time from cardiac arrest to ALS initiation, min (median, IQR)	8 (5–10)	8 (5–10)	8 (6–12)	0.3
Time from ALS initiation to ROSC, min. (median, IQR)	10 (6–22)	6 (3–14)	11 (6–28)	0.06
Time from cardiac arrest to ROSC, min. (median, IQR)*	19 (11–29)	18 (10–26)	22 (15–45)	0.1

Abbreviations: ACE, angiotensin-converting enzyme; ARB, angiotensin receptor blocker; COPD, chronic obstructive pulmonary disease; VF, ventricular fibrillation; STEMI, ST segment elevation myocardial infarction; VT, ventricular tachycardia; ALS, advanced life support; IQR, interquartel range; ROSC, return of spontaneous circulation.
* Characteristics included in multivariate regression analysis.

3. Results

3.1. *Basic characteristics of study population*

During a period of 22 months, 881 patients were presented with OHCA in the city of Prague. ROSC was successfully achieved in 336 (38%) patients and 59 (6%) patients were admitted to the ICU at IKEM in whom physician of EMS crew assumed cardiac aetiology. Hypothermia was indicated and performed in 46 comatose patients (34 men, 12 women; mean age 60.2±12.7 years; range: 19–83 years) who constituted the cohort of our study. Of those in whom hypothermia was not indicated 12 patients were conscious and one patient had melaena on admission. Demographic and clinical characteristics of the cohort are shown in Table 1. The first monitored rhythm on the scene was ventricular fibrillation or pulseless ventricular tachycardia (VF/VT) in 27 (59%) patients, and asystole in 14 (30%) or pulseless electrical activity in 5 (11%) patients. The underlying aetiology of cardiac arrest was coronary artery disease ($n = 31$, 67%), dilated cardiomyopathy ($n = 5$, 11%), or other aetiology ($n = 10$, 22%) as specified in Table 1. Among patients with coronary artery disease ($n = 31$), 22 (71%) patients presented with acute myocardial infarction (16 patients with STEMI) and 17 of them underwent direct PCI. The first documented rhythm at the scene was VF/VT in 61% patients of coronary artery disease group, 80% of dilated cardiomyopathy group, and in 40% patients of other aetiology.

Basic life support was provided by a bystander in 63% cases. Average time from cardiac arrest to the initiation of ALS was 8.4±4.3 min (median 8, IQR: 5–10). Average time from ALS to ROSC was 16±16 min (median 10, IQR: 6–22) and average time from cardiac arrest to ROSC was 24±17 min (median 19, IQR: 11–29).

3.2. *Provided therapy*

Therapeutic hypothermia was provided in all 46 patients. The time from admission to achievement of a goal temperature of 33 °C was 5.0±2.2 h (median 4.0, IQR: 3–6). Urgent PCI was performed in all patients who presented with STEMI (16 pts,

Table 2 – Therapeutic processes and physiological variables at admission and during the initial 24 h.

Characteristics	All patients (N = 46)	Outcome		P-value
		Good (CPC 1, 2) (N = 23)	Poor (CPC 3–5) (N = 23)	
Time from admission to achieving goal temperature (h)	5.0±2.2	5.3±2.5	4.6±1.8	0.5
Urgent percutaneous coronary intervention	17 (37%)	12 (52%)	5 (22%)	0.05
Intra-aortic balloon pump	2 (4%)	2 (9%)	0	
Inotropic agents	24 (52%)	15 (65%)	17 (74%)	1.00
Rebound hyperpyrexia analysed in 41 patients	22 (54%)	12 (55%)	10 (45%)	0.8
Glycaemia (mmol/l)				
Admission	14.5±5.7	13.8±5.2	15.3±6.3	0.4
After 12 h	10.9±5.1	9.9±3.7	11.9±6.1	0.2
After 24 h	10.7±5.1	9.1±3.9	12.3±5.7	0.04
pCO_2 (kPa)				
Admission	6.5±2.3	6.4±2.3	6.6±2.4	0.8
After 12 h	5.1±1.1	4.9±0.7	5.2±1.5	0.4
After 24 h	4.8±0.7	4.6±0.6	4.9±0.8	0.2
BE (mmol/l)				
Admission	−5.2±6.3	−3.3±6.7	−7.1±5.4	0.04
After 12 h	−3.5±4.6	−2.6±3.3	−4.5±5.5	0.2
After 24 h	−4.7±11.3	−2.4±3.3	−7.2±15.5	0.158
Lactate (mmol/l)				
Admission*	5.8±4.1	4.0±4.6	7.3±4.1	0.024
After 12 h	3.4±2.6	2.5±1.1	4.3±3.2	0.045
After 24 h	2.6±1.7	1.9±1.2	3.2±1.9	0.040
Lactate clearance (%), median (IQR)	58 (46–79)	50 (32–79)	58 (51–75)	0.6
MAP (mmHg)				
Admission	91±23	92±20	89±26	0.600
After 12 h	85±16	86±18	84±14	0.641
After 24 h	80±23	79±13	80±30	0.888

Abbreviations: pCO_2, partial pressure of carbon dioxide; BE, base excess; MAP, mean arterial pressure.
* Characteristics included in multivariate regression analysis.

35%) and in one patient (2%) with left bundle branch block. In two patients (4%), intra-aortic balloon pump was used for hemodynamic support after PCI. The median duration of the intensive care was 6 day (IQR: 4–10). Implantable cardioverter-defebrillator implantation had been performed in 8 (35%) patients who were then discharged home. Rebound hyperpyrexia according to definition above occurred in 22 (54%) cooled patients having almost the same prevalence in good and poor outcome groups (50% vs. 45%; $P = 0.7$). Mean blood glucose level was 14.5±5.7, 10.9±5.1, and 10.7±5.1 mmol/l on admission, after 12 h, and 24 h after admission, respectively.

3.3. *Outcome variables*

At 1-month follow-up, 23 patients (50%) had favourable outcome (CPC 1–2), while 23 patients (50%) had poor outcome (CPC 3–5), including 19 with in-hospital death (CPC 5, 41% of total) (Figs. 1 and 2). Both groups differed in age (54.8±12.7 years vs. 65.6±10.3 years; $P = 0.003$), occurrence of VF/VT as an initial rhythm (78% vs. 39%; $P = 0.007$), incidence of acute myocardial infarction as the underlying aetiology of cardiac arrest (63% vs. 30%; $P = 0.02$), and a history of beta-blocker therapy (13% vs. 52%; $P = 0.02$). Regarding laboratory parameters, the good outcome group had significantly lower lactate level at admission, 12 h and 24 h after

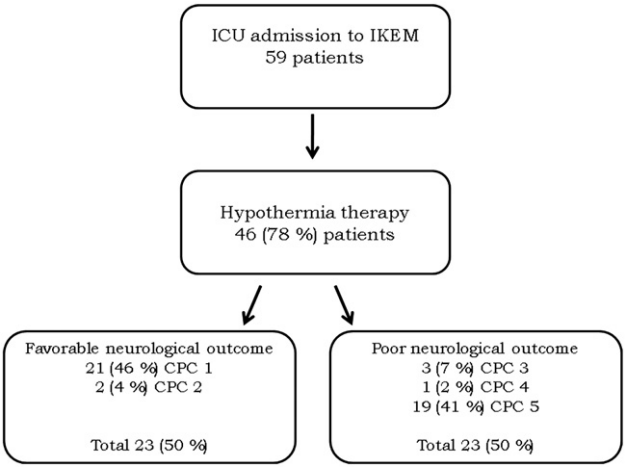

Fig. 1 – Patients admitted to the ICU after OHCA and outcomes of 46 patients who were indicated and treated with hypothermia.

cardiac arrest (4.4±4.6 vs. 7.3±4.1 mmol/l; $P = 0.02$, 2.5±1.1 vs. 4.3±3.2 mmol/l; $P = 0.04$, 1.9±1.2 vs. 3.2±1.9 mmol/l; $P = 0.04$, respectively) (Table 2). Lactate clearance was similar in both groups (median 50%, IQR: 32–79 vs. 58, IQR: 51–75, $P = 0.6$).

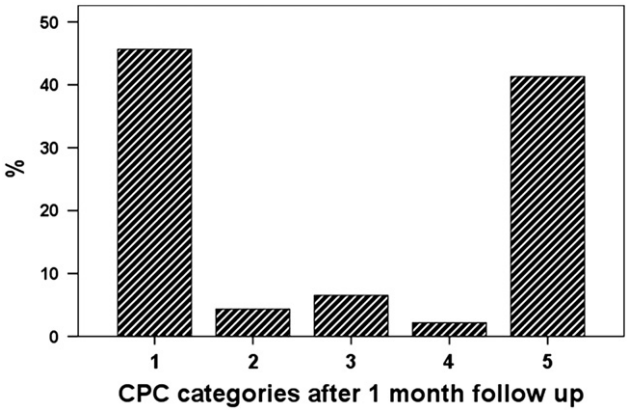

Fig. 2 – The outcome of patients after 1-month follow-up presented in CPC categories.

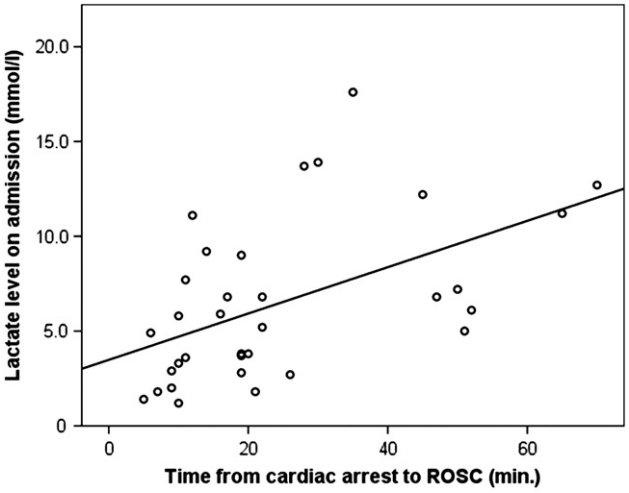

Fig. 3 – Correlation between the lactate level on admission and the time from cardiac arrest to ROSC ($r = 0.512$; $P = 0.002$).

Subsequent multivariate logistical analysis revealed an association of the initial lactate level with the outcome (OR 1.412, 95% CI 1.054–1.892; $P = 0.02$). Furthermore, we found a correlation between lactate level at admission and the time from cardiac arrest to ROSC ($r = 0.512$; $P = 0.002$) (Fig. 3).

3.4. *Independent predictors of favourable outcome*

The following variables were included in multivariate logistic regression model: age, VF/VT as the first documented rhythm on the scene, myocardial infarction as the underlying aetiology of cardiac arrest, lactate level on admission, and the time from cardiac arrest to ROSC. The Homser–Lemeshow test indicated that the model adequately fits the data ($\chi^2 = 10.8$, $df = 8$, $P = 0.2$). Favourable outcome (CPC category 1–2 at 30 day after admission) was associated with younger age, myocardial infarction as the underlying aetiology of cardiac arrest and lower level of lactate on admission (Table 3).

4. Discussion

Despite decades of therapeutic changes for OHCA, the survival with favourable neurological outcome remains very poor. The main objectives of this study were to present our experience with the latest therapeutic approaches influencing beneficially survival rate after OHCA, and to identify predictors of survival with favourable outcome after implementation of these approaches.

Prevalence of survival with favourable neurological outcome (CPC 1–2) at 1-month of follow-up in our 46 analysed patients reached 50%. This high proportion of successful outcome is similar to the original work of Bernard and colleagues in 43 patients who were also treated with hypothermia [11]. However, it is higher in comparison to previous studies from other centres, which may be due to several reasons [6,14–19]. Firstly, as reported in previous studies, majority of circulatory arrests are of cardiac aetiology [20,21]. In the present study, cardiac aetiology of the arrest was confirmed in 67% of patients. In addition, high proportion of cases suffered from acute myocardial infarction as underlying aetiology of the arrest (overall 48% and STEMI in 35% patients). This may reflect a specific situation in the Czech Republic as all patients with suspected acute myocardial infarction are transported primarily to specialized centres with catheterization laboratories. Secondly, cardiac arrest due to VF or VT is generally associated with better survival rate after OHCA [22–24]. VF or VT are amenable to early defibrillation and indicate collapse of the circulation without previous global hypoxia. This is in agreement with our findings, where VF/VT was present in 59% of patients and the survival rate after ICU admission in this subgroup reached 67% (ROSC median 6 min, IQR: 4–14). On the other hand, the survival rate of patients with documented asystole or pulseless electrical activity was only 26% (ROSC median 11 min, IQR: 6–28). Finally, our results may reflect the efficacy of EMS in the city of Prague.

However, other factors may affect the outcome after OHCA. In the present study, we did not analyse the prevalence of cardiogenic shock after ROSC because it could not have been accurately defined. On the other hand, both ionotropic agents and intra-aortic balloon pump were used in our population with similar frequency. This is in agreement with previous studies, where cardiogenic shock did not affect the effectiveness of post-OHCA therapy [12,25].

Interestingly, an association between beta blocker therapy and poor outcome was found. This association may be due to the fact that the majority of subjects in the present study who had been on beta blocker therapy had also had CAD history. These patients with CAD history probably had more severe health status before cardiac arrest, which could adversely affect their outcome after cardiac arrest.

Hyperpyrexia has been associated with significantly increased risk of brain death after OHCA [6,26,27]. The international Liaison Committee on Resuscitation (ILCOR) recommended the use of hypothermia after VF and OHCA as it improves the neurological outcome of comatose patients after cardiac arrest [3,11,12,28]. Hyperpyrexia is commonly observed after re-warming from hypothermia. However, it

Table 3 – Predictors of favourable neurological outcome, final multivariate model.

Prognostic factor	Adjusted odds ratio	95% CI	P-value
Age (years)	1.142	1.023–1.274	0.02
Acute myocardial infarction as underlying aetiology of cardiac arrest	0.052	0.005–0.552	0.01
Lactate on admission (mmol/l)	1.436	1.063–1.941	0.02

remains unknown if rebound hyperpyrexia after cessation of cooling is associated with adverse outcome. In this study, rebound hyperpyrexia occurred with similar frequency in good and poor outcome groups.

Some studies reported that hyper- or hypoglycaemia can be associated with brain injury after OHCA [29,30]. Hyperglycaemia is common in patients after successful cardiac resuscitation from OCHCA and is associated with poor neurological outcome [29,30]. However, strict control of blood glucose levels may lead to harmful hypoglycaemia [31]. The multicenter analysis of patients admitted to ICU after cardiac arrest demonstrated an association between hospital mortality and the lowest blood glucose concentration measured during the first 24 h [13]. Beiser et al. [32] have recently published a paper confirming a U-shaped relationship between maximum and minimum blood glucose and hospital survival in non-diabetic patients after cardiac arrest. This suggests that in patients resuscitated after cardiac arrest, a mild hyperglycaemia should be targeted. However, there is no consensus on blood glucose measures best correlate with outcome. In the present study, the target value of blood glucose was below 10.0 mmol/l and analysed three values; at admission, after 12 h and after 24 h of admission. In the good outcome group, the blood glucose level was well controlled with a mean glycaemia below 10 mmol/l. Blood glucose level measured 24 h after admission might be a good indicator of worse outcome while patients with poor outcome had significantly higher glucose level (9.1 ± 3.9 mmol/l vs. 12.3 ± 5.7 mmol/l; $P = 0.04$).

Other studies have evaluated the significance of lactate level in patients with ROSC after cardiac arrest [19,33]. Lactate is a byproduct of anaerobic metabolism after glycolysis and is often considered as a measure of tissue hypoxia. Not surprisingly, some authors have documented an association between plasma lactate level on admission and neurological outcome after OHCA for VF [34]. Similar findings have been found in a recently published prospective study in patients treated with hypothermia after cardiac arrest [19]. In the present study, there were statistical differences between patients with good and poor outcome not only in the baseline lactate level, but also in samples obtained 12 h and 24 h later. Although we found a correlation between the plasma lactate level on admission and the time from cardiac arrest to ROSC, lactate level on admission was a stronger predictor of outcome rather than the mean time of ROSC. This suggests that the quality of early CPR (level of global hypoxia), rather than time to ROSC is more relevant for outcome after OHCA. This is in agreement with a previous report from Oddo and colleagues, where lactate level on admission was important outcome predictor independently of time of ROSC [19]. Higher lactate level in the poor outcome group after 24 h of admission could be explained either as a hypoxia-related higher production in the tissue or as a result of reduction in lactate clearance. Since the calculated 24 h lactate clearance was similar in both study groups, we believe that the higher lactate level persisting 24 h after OHCA in the poor outcome group was due to persisting tissue hypoxia. Along these lines, Rivers et al. [35] have shown a significant impairment of systemic oxygen extraction in post cardiac arrest patients. Reasons for such a defect in systemic oxygen utilization may reflect a persistence of microcirculatory dysfunction or an intracellular enzymatic defect.

Our study had several limitations. Firstly, it is a retrospective, non-randomized, single centre observational study. Secondly, our cohort may not represent all patients with OHCA. Due to the existence of direct PCI capacity in our centre, patients with OHCA due to VF in STEMI may be more represented.

5. Conclusions

After implementation of recent advances in post-arrest resuscitation care into clinical practice, a favourable outcome was reached in half of OHCA survivors treated at our hospital. Lower age, acute myocardial infarction as a cause of the arrest and lower initial lactate level were found useful predictors of favourable outcome in patients treated according to the recent treatment recommendations of OHCA.

Conflicts of interest

All the authors declare no conflict of interest.

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