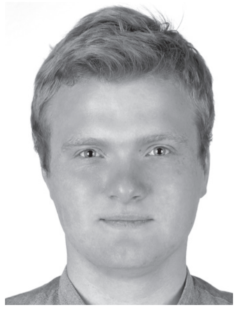
Anestezjologia • Ratownictwo • Nauka • Praktyka / Anaesthesiology • Rescue Medicine • Science • Practice

ARTYKUŁ POGLĄDOWY / REVIEW PAPER
Otrzymano/Submitted: 10.09.2021 • Zaakceptowano/Accepted: 13.11.2021

The complications of cardiopulmonary resuscitation – how to prevent?

Powikłania resuscytacji krążeniowo-oddechowej – jak zapobiegać?



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Abstract

Complications of chest compressions are very common and difficult to avoid. The most frequent are definitely rib and sternal fractures. Most common complications of airway management in cardiopulmonary resuscitation (CPR) are: failure in first attempt, leakage during ventilation (both leading to hypoxemia), regurgitation of gastric contents, epistaxis and injuries of oral cavity. Complications of intravenous and intraosseous accesses and infusions are also common and are unavoidable. Complications of defibrillation may affect operator who delivers shocks and he can suffer from: mild burns, paralysis, tingling, soreness of damage of the body. Defibrillated person could suffer from muscle necrosis, burns and reversible renal failure. Post-cardiac arrest syndrome is a critical condition, characterized by hyper inflammatory state, brain injury, myocardial and renal dysfunction. In post-resuscitation care early recognition of the CPR-related injuries and consequences of cardiac arrest, is of critical importance. *Anestezjologia i Ratownictwo 2021; 15: 164-174. doi:10.53139/AIR.20211517*

Keywords: resuscytacja krążeniowo-oddechowa, uciski klatki piersiowej, zabezpieczenie dróg oddechowych, dostęp dożylny, dostęp doszpikowy, defibrylacja, zespół poresuscytacyjny

Streszczenie

Powikłania ucisków klatki piersiowej są dość częste i trudne do uniknięcia. Najczęściej dochodzi do złamań żeber i mostka. Najczęstsze komplikacje związane z zabezpieczeniem dróg oddechowych podczas resuscytacji krążeniowo-oddechowej (RKO) obejmują: niepowodzenie przy pierwszym podejściu, nieszczelność podczas wentylacji (oba czynniki prowadzą do hipoksemii), regurgitację, krwawienia ze śluzówek, uraz jamy ustnej. Powikłania dostępów dożylnych i doszpikowych, infuzji, również zdarzają się często i są niemożliwe do uniknięcia. Powikłania defibrylacji mogą dotyczyć zarówno osoby wykonującej defibrylację, u której może dojść do poparzeń, porażeń, mrowień, bolesności uszkodzonej części ciała. W przypadku osoby defibrylowanej może dojść do martwicy mięśni, poparzeń skóry i odwracalnej niewydolności nerek. Zespół poresuscytacyjny jest okresem który charakteryzuje się stanem prozapalnym oraz uszkodzeniem:

mózgu, mięśnia sercowego i nerek. W opiece poresuscytacyjnej należy zwrócić uwagę na wczesne wykrycie komplikacji wynikających z resuscytacji oraz następstw zatrzymania krążenia. *Anestezjologia i Ratownictwo 2021; 15: 164-174. doi:10.53139/AIR.20211517*

Słowa kluczowe: cardiopulmonary resuscitation, chest compressions, airway management, intravenous access, intraosseous access, defibrillation, post-cardiac arrest syndrome

Introduction

Cardiopulmonary resuscitation (CPR) is performed in cardiac arrest to restore the heart rate and ventilation. High quality CPR is crucial in restoring vital signs. Unfortunately this saving life activities may cause some complications. Is it possible to improve methods of efficient CPR and save patient from those complications? [1] A lot of researches are available and the statistics of CPR-related injuries vary a lot. The percentage of people who sustain injured during CPR is really difficult to determine. Some researches show that the appearance of the injuries is associated with such issues as older age, gender, public location of the cardiac arrest and initial shockable rhythm [2]. However, those factors are not obvious and do not appear in every analysis. Airways management, chest compressions, defibrillation and intravenous or intraosseous access are significant methods used during CPR procedure. The aim of this study is to present the complications of different recommended methods of treatment used during cardiopulmonary resuscitation.

Chest compressions

Performing CPR is necessary in life-threatening situations. It is carried out by both specialists – medical staff – and by CPR bystanders. The procedure itself looks easy, but it is really not as simple as it looks – therefore the complications are indispensable. Complications of chest compressions are common and relate to 'just' some mechanical chest injuries. They frequently lead to internal injuries, which may be fatal. European Resuscitation Council (ERC) in the guidelines published in 2021 recommend chest compressions to be done same as before, at a depth of 5-6cm, at least 100/min, in the centre of the chest. The difficulty is, that every man differs from each other, so the rib cage is not the same – so this leads to the most popular and most frequent complications, which are definitely rib and sternal fractures [2-9]. We have summarized, in our opinion, the most important complications of chest compressions reported by some researches. They are presented in Table I. Additionally we showed some interesting statistics.

Scientists divide rib fractures into some groups – single, multiple, one side, bilateral etc. [2,5]. One of the researchers suggested, that increased number of these complications is caused by the improvements in CPR-recommendations – which are connected with the greater depth and higher speed of compressions [4]. The factors affecting the probability of skeletal chest injuries (SCI) vary depending on studies, but the most often repeated are older age [5,6,9,10], male gender [2] and longer duration of CPR, which significantly increases the possibility of rib fractures [5,9,11]. A post mortem computed tomography (PMCT) research showed no significant differences in CPR-complications associated with gender, but pointed out that the depth of compressions recommended by the guidelines could be too deep for some populations, especially small people and could cause extra SCI.[5] Some reports referred that the duration of the attempt may not always be a predisposition to CPR-related injuries [2]. One publication pointed out, that there is a big difference between the quality of out-of-hospital and in-hospital CPR – the first one is approved to be an independent risk factor for injuries [6].

Performing CPR is very exhausting and the quality of compressions dramatically decreases during performance. The mechanical chest devices are getting more popular, so more and more chest-compression-related injuries are noticed [10]. There are two different studies that showed, that none of the injuries resulting either from mechanical or manual CPR was fatal in the investigated groups [10,11]. In one study the mechanical CPR caused higher amount of rib fractures, [10] and in the second one CPR-method (mechanical vs. manual) did not show differences in the existence of SCI [11].

Inseparable aspect of rib and sternal fractures, are intra-thoracic injuries or soft tissue injuries and visceral injuries following the SCI. The mechanism is based on mechanical tissue damage when using forces during chest compressions. They are less common and do not appear regularly [7], but there are some interesting cases reporting such injuries [7,8]. We have summarised some interesting case reports in Table II. Cardiac ruptures [2] and injuries of major vessels were reported. Additionally mediastinal haemorrhage [3,9], haemothorax [3,8,9], pneumothorax [3,9], pneumomediastinum[3,9], internal mammary artery (IMA) injuries were reported [9,12]. The cause of these injuries was often ambiguous, but the proposed mechanism was fracture of ribs and sternum [12]. S. Tokioka et al. presented a case of an old man, who had IMA injury related to CPR, but the hypothesis of chest-wall injury was not confirmed, so then the authors suggested the role of shear stress in CPR-related injuries [12]. One study focused on intra-thoracic injuries which were lung and heart contusions and lung lacerations [8]. According to this study all intra-thoracic injuries became relevant while gaining the return of spontaneous circulation (ROSC), and if not – there was no impact of intra thoracic injuries on the victim's health or death [8]. It shows also, that victims with intra-thoracic injuries are more likely to have rib fractures with protruding edges. [8] Some cases of injuries are qualified as inseparable and related to the last attempt to save somebody's life [7]. Abdominal injuries such as traumatic gastric perforation were described [13]. This kind of complications can be serious, but rarely fatal [13].

The complications of chest compressions are very common and difficult to avoid because every CPR is performed by another team, the patients are different, in different age. Imaging patients who survived CPR is an excellent way to identify and draw conclusions how to reduce the number of complications [3,5] and improve the quality of CPR. Some authors pointed out, that post-mortem computed tomography is an excellent way to reduce CPR-related complications [5].

Airway management during cardiopulmonary resuscitation – complications

Appropriate airway management during cardiopulmonary resuscitation is one of the important factors in increasing probability of return of spontaneous cir-

Table I. Percentages of Skeletal Chest Injuries (SCI) and some popular iatrogenic injuries described by the authors

Tabela I. Procent występowania urazów kostno-szkieletowych klatki piersiowej oraz innych częstych powikłań opisanych przez autorów

Authors and year of publication	Number of analysed cases	Rib fractures	Sternal fractures	Sternocostal separations	Additionally iatrogenic injuries
P. Setälä et al. 2018 [2]	149	43% in total	15% in total		heart injuries
E. Kralj et al. 2015 [4]	2148	77% men 85% women	59% men 79% women	33% men 12% women	among others liver and spleen injuries
Y. Kashiwagi et al. 2015 [5]	223	70%	8%		pneumothorax
W. Takayama et al. 2018 [6]	472	38%			pneumothorax
A. Deliliga et al. 2019 [14]	88	26%	17%		soft tissue injuries
D. Smekal et al. 2014 [10]	83 (manual) 139 (mechanical)	65% 79%	54% 58%		retrosternal bleeding, mediastinal bleeding, epicardial bleeding, pericardial bleeding, pneumothorax
G. M. Dunham et al. 2018 [3]	39	85%	31%		mediastinal haemorrhage, pneumothorax, pneumomediastinum, hemothorax, liver injuries
L. Ihnát Rudinská et al. 2016 [8]	80	73,7%	66,3%		lung contusions and lacerations, hemothorax, heart contusion hemopericard

Table II. Some interesting examples of chest compression-related injuries except from skeletal chest injuries (SCI) – single case reports
Tabela II. Interesujące przykłady powikłań ucisków klatki piersiowej, z wyłączeniem urazów kostno-szkieletowych – pojedyncze opisy przypadków

Authors and year of publication	Injuries except from skeletal chest injuries (SCI)
A.S. Williams et al. 2016 [7]	partial separation of atheromatous plaque
S. Tokioka et al. 2018 [12]	internal mammary artery injury
Y. Arai et al. 2017 [13]	traumatic gastric perforation
S. Haj-Yahia et al. 2020 [15]	diaphragmatic rupture with herniation of abdominal organs

culation (ROSC) in both groups of patients, including in-hospital (IHCA) and out-of-hospital cardiac arrest (OHCA).

We would like to briefly introduce the topic of airway management by adding a figure, which describes the methods depending on difficulty in using (Figure1).

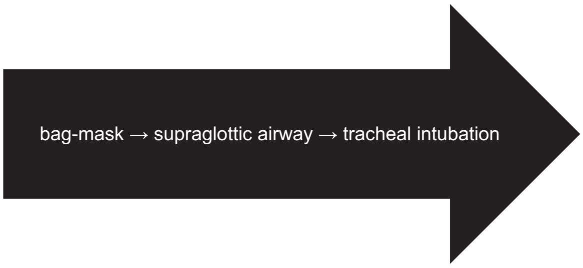

Figure 1. The methods of airway management depending on difficulty in using
Rycina 1. Metody zabezpieczenia dróg oddechowych w zależności od stopnia zaawansowania

Nowadays, rescuers have a variety of equipment and methods to manage the airway successfully, however there is a variable chance of complications which may be caused. Most common complications of airway management during CPR include: failure in first attempt, leaks in ventilation (both leading to hypoxemia), oesophageal obstructions and regurgitation of gastric contents, epistaxis, soft tissue oral cavity and dental injuries. Rare complications include neuropraxic injury of the recurrent laryngeal, lingual, and hypoglossal nerves (caused by cuff hyperinflation and direct pressure to surrounding soft tissues). Basing mostly on observational studies, risk of complications due to airway management during CPR correlates with: (a) the method and equipment used (b) environment where the insertion is performed (OHCA/IHCA) (c) patient's profile (obese, traumatic) (d) experience of rescuer.

Bag-valve mask (BVM) - not differentiated between OHCA and IHCA

B.J. Stone et al. found that in 466 patients who were ventilated with the Bag-valve mask alone (BVM) or BVM followed by endotracheal tube placement, the incidence of regurgitation during CPR was 12.4%. The incidence of regurgitation following CPR for the same group was 1.5%. They compared these results with laryngeal mask airway (LMA) used as the first line airway device (in 86 patients) - the incidence of regurgitation during CPR was 3.5%. None of the patients in this group regurgitated after CPR. Lastly, for the 170 patients who were ventilated with a BVM prior to insertion of an LMA, the incidence of regurgitation during CPR was 11.8%, with an incidence following CPR of 4.7%.[16]. If the recommendation of reducing tidal volumes to 400 – 600 ml during resuscitation is widely implemented, this may reduce the incidence of regurgitation.[17]

Complications related with out-of-hospital cardiac arrest (OHCA)

In the OHCA paramedics use a variety of equipment and technics to manage patient's airway. The comparison of endotracheal intubation (ETI) [18,19] with supraglottic airway (SGA) [18-21] was done, which used intubating laryngeal mask airway (ILMA), [20] i-gel™, [21] and laryngeal tube (LT) [19]. In a prospective observational trial, L. Tritsch et al. declared high effectiveness of ILMA when used by trained nurses.[20] within a group of 302 OHCA patients after ILMA placement, but before an attempt for intubation obstruction or major leaks were observed in 12 patients (4%). Regurgitation occurred in 2 patients (0,7%). After endotracheal tube placement through the ILMA, within a group of 254 intubated patients, 12 (5%) were oesophageal or proved obstructed. Likewise, use of i-gel™ was proved to have low impact on complications when used during CPR [21]. It helps to prevent complications like oesophageal obstructions and therefore regurgitation of gastric contents. A moderate leak in ventilation occurred in 17% and a major leak with no chest rise in 3% patients.

In a prospective study, J.U. Müller et al. [22] investigated the use of the laryngeal tube disposable by paramedics in adult OHCA patients over a 3.5-year period. The analysis included 130 insertion attempts. Complications involved 29 cases (22%), including cuff pressure problems, vomiting/regurgitation, not possible fixation, tongue swelling, and laryngeal spasm.

In another research comparing ETI with LT insertion, initial laryngeal tube insertion resulted in 2,9% greater likelihood of 72-hour survival.[19] Additionally, ETI resulted in more complications: 3 or more insertion attempts (18.9% vs 4.5%), unsuccessful initial insertion (44.1% vs 11.8%), unrecognized misplacement or dislodgement (1.8% vs 0.7%). There were no significant differences in oropharyngeal or hypopharyngeal injuries (0.2% vs 0.3%) [19].

Complications related with in-hospital cardiac arrest (IHCA)

Except for commonly used methods during OHCA, in IHCA we have quick access to more innovative and less portable devices. Additionally, we know much more about the patient staying in a hospital. In a clinical observational study S.O. Park et al. [23] achieved a high success rate for the first ETI attempt using video laryngoscopy (GlideScope®) with notably few chest compression interruptions, regardless of the physicians' varying experience with successful ETI in the past. In another research longer chest compressions interruptions occurred using direct laryngoscopy (4.0 [1.0–11.0] s) than video laryngoscopy (0.0 [0.0–1.0] s) The complications included oesophageal intubations and dental injuries, however there was no significant difference between its rate [24].

Based mostly on the observational studies, risk of complications due to airways management during CPR correlates with: (a) the method and equipment used [18-21] (b) adjusting method to medical staff's experience [20,21] (c) patient's profile (obese, traumatic)[25,26] (d) environment where the insertion is performed (OHCA [18-21,25,26] /IHCA [23,24]). The current ERC guidelines (2021) recommend using SGA for both OHCA and IHCA, leaving ETI only for trained rescuers with a high success rate in intubation attempts.

Complications of intravenous and intraosseous access

Intravenous and intraosseous accesses are indispensable in CPR, because of their significant rule. By those accesses it is able to deliver drugs and fluids to the patient circulation, consequently increasing the probability of effective CPR. That great advantage of infusions may also have some repercussions.

The number of potential complications in those techniques is very high. Complications of intravenous accesses and infusions are more common, but are also less severe. Starting with gaining intravenous accesses M.K. Chaudhary et al. described the following complications hematoma, bleeding and arterial bleeding [27]. P. Kaur et al. added hemorrhage and nerve injuries [28]. According to N. Marsh et al. unacceptable peripheral catheter failure appeared in over two-third of injections. This research showed that the most common complications of peripheral intravenous infusion were phlebitis – inflammation of the vein, infiltration – leak of fluid into extravascular tissue - and occlusion. The frequency of partial dislodgement, leakage or accidental removal was also high [29]. R. Piper et al. noticed that even a serious systemic infection may occur induced by phlebitis or thrombophlebitis [30]. Another complications which are also common were redness and swollen place of puncture. The foregoing complications were mentioned by Y. Liu et al. They suggested also that a modified puncture method, which means leaving 2 mm of the needle catheter outside the puncture point could decrease number of failures [31].

Complications of intraosseous infusions seem to be more serious due to the deeper interference into the body. P. Hallas et al. in their research compared complications of intraosseous accesses in Scandinavia. They divided complication into three groups – complications at the beginning, during the procedure, and late complications. The most common complications at the beginning, which is not exactly a complication, but a problem with sitting the needle, were the difficulty to aspirate the bone marrow and the difficulty to penetrate the periosteum. Additionally, patient's discomfort and pain, bended or broken needle or difficulty to identify correct anatomical site were also present. Slow infusion despite use of pressure bag and displacement after insertion were the most frequent complications in use, whereas osteomyelitis, skin infection and compartment syndrome, were the only late complications [32]. C. Landy et al. in a letter to the editor marked that extravasation can be a cause of compartment syndrome [33]. This syndrome can also be connected with another late complication – which is acute intracompartmental hemorrhage [34]. K.M. Thadikonda et al. described an unusual location for compartment syndrome – the deltoid compartment. They also added extravasation of infused agents as a late complication [35]. Tibial intraosseous access can also lead to soft tissue laceration. R. Bromberg et al. described a case report of an obese patient suffering from this complication [36]. N.L. Henson et al. put emphasis on tibial subacute osteomyelitis with intraosseous abscess. It is also an uncommon late complication. Infiltration was indicated as more frequent late complication, but fat embolism and air embolism were also present [37]. Another infrequent late complication was the septic arthritis of shoulder joint with gas gangrene, which was described by M.N.H. Khan et al. [38]. Table III summarizes this chapter. Intravenous access is safer then intraosseous and leads to less complications, which are also less severe hence European Resuscitation Council recommends intravenous route at the beginning and, if unsuccessful, then intraosseous.

Complications of intravenous and intraosseous accesses and infusions are unavoidable, because of the interference to human body. There is no perfect human that suits to anatomy books. Those differences lead to errors.

Defibrillation – complications

Defibrillation is a kind of treatment, recommended for pulseless ventricular tachycardia and ventricular fibrillation. Early CPR and defibrillation play key role in both out-of-hospital (OHCA) and in-hospital cardiac arrest survival (IHCA) [39,40] and positive neurological outcome [41]. Every minute of delay in defibrillation decreases its effectiveness and chance of restoration of pulse by 5–7% [40] and causes 9% decrease in neurologically intact survival [41]. If the defibrillation can be provided within 5-10 minutes, patients may survive without neurological outcomes [25,42].

Automated external defibrillators (AED)

It is known, that placing AED in certain locations improve OHCA survival. Also many studies revealed that public-access defibrillation programs improve rate of survival among patients with OHCA [43]. Although there are some reasons, why automated defibrillation may conduct not properly. J.A. Zijlstra et al. analysed 1114 AED's recordings with 3310 analysis periods where in 1091 cases device gave advice to shock and in 2219 cases device did not give advice. Among 1091 shock advices 44 of them were given incorrect (44%). Wrong indication for defibrillation by the AED arose due to the fault of the operators which was a movement during chest compressions (in 28 cases) and caused by the device-related errors (in 15 cases). One reason remained unknown. Of the 2219 contraindications for shock, 26 of them were given incorrectly: twenty due to device-related errors and six due to operators' fault.

Table III. Intravenous and intraosseous access complications in descending order - presented in the literature
Tabela III. Powikłania dostępów dożylnych i doszpikowych w malejącej częstości występowania

Intravenous access		Intraosseous access	
Complications by cannulations (access)	Late Complications (infusion)	Complications by needle insertion (access)	Late Complications (infusion)
- hemorrhage [28] - hematoma [27] - bleeding [27] - arterial bleeding [27] - nerve injury [28]	- phlebitis [29,30] - infiltration [29] - occlusion [29] - partial dislodgement [29] - leakage [29] - accidental removal [29] - thrombophlebitis [30]	- difficulty to aspirate the bone marrow [32] - difficulty to penetrate the periosteum [32] - patients pain and discomfort [32] - bended or broken needle [32] - difficulty to identify correct anatomical site [32]	- compartment syndrome [32] - osteomyelitis [32] - skin infection [32] - acute intracompartmental hemorrhage [34] - extravasation of infused agents [35] - soft tissue laceration [36] - tibial subacute osteomyelitis with intraosseous abscess [37] - embolism (fat or air) [37] - septic arthritis [38]

Moreover in 59 cases, the shock was not delivered even it was indicated. It resulted from operators' mistakes such as failure to deliver the shock, removing AED before shock delivery, pressing "off" button on device and others [44]. These faults could lead to a patient's death due to asystole. In general, automated external defibrillators are safe [40], precise both in recognizing and shocking unstable cardiac rhythms.[45] The vast majority of accidents occurred as a result of improper use of the device or accompanying circumstances during the process [44].

Manual defibrillation

Defibrillation may cause complications not only to the patients but also to operators of defibrillators. Despite possible danger induced by electricity during defibrillation including: myocardium necrosis, cardiac arrhythmias, burns, nervous system injury, muscle damage and other systems failure [46], few cases of serious damage can be found in the literature.

A survey was conducted among emergency personnel working in King County, Washington revealed that during 10 years of treating patients with defibrillation, 8 injuries associated with defibrillation occurred to paramedics, EMTs (emergency medical technicians) and EMTs-Ds (emergency medical technicians trained in defibrillation). The most threatening accident was caused by crack in defibrillator paddle. Paramedic who received a shock blacked out for 1 to 2 minutes and has been hospitalized for 3 days. He suffered from premature ventricular contractions requiring lidocaine for 24h and muscle spasms in the chest and arms continued for several weeks. The crack in paddle wasn't recognizable during visual inspection.

Other injuries like tingling in arm for 30 minutes, mild soreness to arm, shock to leg, shock to tips of fingers, shock to hand and lethargy for several minutes and shock which knocked paramedic away from patient were caused by contact with patient or stretcher. All these injuries were reversible and didn't cause severe complication. Also data obtained from the Product Monitoring Branch of the Food and Drug administration deliver information about 13 injuries of the operator of defibrillators, 10 of them were caused during resuscitation and 3 during training. They were caused for example by arch from paddle to electrode on patient, accidental discharge during charge and others causing burns to operator and also patient [47].

There is known a case of 61 years old patient who was treated in a hospital with recurrent VT and VF [48]. 19th attempts of direct current (DC) cardioversion and defibrillation were initiated and finally restored sinus rhythm. Patient presented increased: myoglobin to 231ng/ml (normal upper value 76ng/mL), creatine kinase to 38,687 (upper value 190IU/L), plasma creatinine to 4,4 mg/dL and developed oliguria without hypotension then anuria on 3th day of observation. Reversible myoglobin uric renal failure is caused due to rhabdomyolysis after electric shocks. Myoglobulin release after muscle injury leads to obstruction of renal tubules. Technique of scanning with 99mTc pyrophosphate may reveal extensive muscle injury caused by DC shocks.

Defibrillation may also lead to skin changes with serious histological damage. L. Danielsen et al. [49] described cases where patients presented red rings on skin surrounding defibrillation pad placement. Biopsy of these alterations taken day after defibrillation revealed small epidermal necrosis in the cathode and anode area.

M. E. Ward described a case in which a patient was burned by electricity during defibrillation. It caused a fire of bedding and lead to severe burns. This accident could be enhanced by oxygen releasing from disconnected breathing system lying close to the patient's head [50].

Defibrillation can have destructive impact on muscle structure. U. Vogel et al. presented a case of 37-years-old man who received 7 defibrillations due to ventricular fibrillation. Patient presented increase of total creatine phosphokinase up to 7758 U/1, constantly falling down to 26 U/l on 10th day of hospitalization. Unfortunately the patient died on the 13th day of admission. Histological examination and gross autopsy of right pectoral muscle revealed changes indicating serious muscle damage [51].

Post-cardiac arrest syndrome

Post-cardiac arrest syndrome (PCAS) is a complex, systemic inflammatory condition characterized by four critical issues: post-cardiac arrest brain injury, myocardial dysfunction, systemic ischemia/reperfusion response, and persistent coagulopathy. This syndrome consists of five phases, including: the immediate phase, which occurs 20 minutes after return of spontaneous circulation (ROSC), early phase observed from 20 minutes to 6-12 hours after ROSC, intermediate phase observed from 6-12 to 72 hours after ROSC, followed by recovery phase which occurs 3 days after ROSC, and finally, rehabilitation phase [52]. Disturbances in oxygenation and ventilation are the most important factors which exacerbate neuronal injury and organ dysfunction and are associated with a poor outcome after cardiac arrest [53]. Whole-body ischemia and reperfusion syndrome trigger a systemic inflammatory response. The immunological aspects of the PCAS and resuscitation disease encompass hypercytokinemia, high levels of circulating adhesion molecules, the presence of plasma endotoxin, and overactivity of leukocytes, leading to a hyperinflammatory state [54]. It has also been shown that matrix protein cyclophilin D, which regulates the opening of the mitochondrial permeability transition pore, plays a key role in the pathophysiology of PCAS [55].

Comprehensive critical care which includes mechanical ventilation, hemodynamic support, and close monitoring of blood parameters is of critical importance for a favourable outcome. The monitoring of oxyhemoglobin saturation and its maintenance between 94% and 100% is recommended. Target temperature monitoring and therapeutic hypothermia strategy prevents tissue damage and improves survival and neurological outcome. At the stage of induction and maintenance of therapeutic hypothermia, one must be watchful to potential adverse effects, such as coagulopathy, electrolyte disorders, tachy- and brady-arrhythmias, hyperglycaemia, vulnerability to infections. Monitoring of the laboratory parameters comprises: coagulation parameters, blood gases, blood glucose level is aimed at the potential administration of insulin and antibiotic therapy. Thereafter, rapid rewarming should be avoided to prevent cerebral edema and seizures [56,57].

Evaluation of the metabolic state of the resuscitated patients includes blood gases, glucose, electrolytes, ammonia, and lactate levels, as well as biochemical markers of renal and liver functions, are further indispensable components of post-cardiac arrest care.[58,59] To identify and treat the coronary artery obstructive disease, early invasive coronary angiography should be considered during the post-resuscitation phase of myocardial dysfunction [59].

In cardiac arrest (CA) survivors, hypoxic ischemic brain injury is a leading cause and long-term neurological disability. This disorder is associated with reperfusion injury due to impaired cerebral vascular regulation, microcirculatory dysfunction, variations in carbon dioxide pressure, hyperoxia, hyperthermia, hypoxemia, and concomitant anemia. Consequently, significant neurological impairment ranging from mild cognitive disabilities to severe comatose state are frequent long-term complications of CA. Close monitoring of core temperature is therefore of paramount importance in limiting secondary brain injury [60].

Myocardial dysfunction is the next consequence of CA, accountable for the majority of sudden cardiac deaths (SCD), which predominantly occurs in patients with advanced heart failure or cardiomyopathy and with primary non-cardiac diseases, such as pulmonary embolism as well. Furthermore, epinephrine, the principal drug administered to patients during CPR, due to its beta-adrenergic effects, can contribute to tachyarrhythmias and increase myocardial oxygen consumption. Epinephrine also induces thrombogenesis and platelet activation which can lead to coronary ischemia aggravated, in turn, by epinephrine-related vasoconstriction [61]. Whereas tachyarrhythmias and bradyarrhythmias are associated with a high risk of recurrence and may contribute to a secondary CA [56]. Sudden cardiac arrest (SCA) survivors with different types of arrhythmias, if no reversible cause is identified for the cardiac arrest, implantable cardioverter-defibrillator (ICD) should be considered as the mainstay in the prevention of secondary SCA. ICD approach has also been proved to be significantly more effective in reducing long-term mortality in SCA survivors compared to antyarrhythmic medications, such as amiodarone [62]. Moreover, the effect of untreated CA, that is no-flow time, on the postresuscitation myocardial dysfunction has been studied on an animal model. It has been shown that longer no-flow durations caused greater postresuscitation myocardial dysfunction which correlated with lower cardiac output (left ventricular ejection fraction, LVEF) and higher cardiac troponin serum level [63].

In post-resuscitation care, the medical evaluation of a patient should be targeted at the recognition of complications including the physical examination, laboratory tests, and imaging. Maintenance of a stable patient's cardiac and neurological condition in post-resuscitation care is of critical importance, albeit careful observation and monitoring for early recognition of sequelae of the resuscitation itself. Post-resuscitation evaluation should also be directed toward discrimination between CPR-related injuries and accident-related injuries [64]. Injuries of the rib cage, upper airway injuries, abdominal and pulmonary traumas need to be taken into account. The whole body computed tomography is a useful tool in diagnosing CPR-related injuries [3,65].

Konflikt interesów / Conflict of interest
Brak/None

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