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Review

The necessity of conversion from coronary care unit to the cardiovascular intensive care unit required for cardiologists

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ABSTRACT

The in-hospital mortality rate of acute myocardial infarction (AMI) has dramatically decreased due to the treatment at the coronary care unit (CCU), especially with the progress of arrhythmia therapy and reperfusion therapy. On the other hand, severe heart failure and multiple organ failure are increasing due to aging populations and multiple organ diseases. As a result, patients with AMI without complications are less likely to be admitted to the CCU, and cardiologists staying in the CCU have also decreased. The mortality rate is high when complications such as cardiogenic shock, cardiac rupture, and in-hospital cardiac arrest occur in AMI, therefore careful intensive care even in low-risk AMI is necessary. For cardiologists, mechanical ventilation, renal replacement therapy, or infection control are necessary for cardiovascular intensive care, and integrated multidisciplinary care coordinated by skilled intensive care physicians, nurses, respiratory therapists, physiotherapists, pharmacists, nutritionists, social workers, and clinical engineers is important. Therefore, for the critical care of cardiovascular diseases, it is necessary to convert from CCU to the cardiovascular intensive care unit.

Contents

History of coronary care unit and its achievements

Cardiopulmonary resuscitation (CPR) and electrical defibrillation established in 1960, were utilized in the life saving of cardiac arrest due to acute myocardial infarction (AMI) and led to the establishment of the coronary care unit (CCU) [1]. In-hospital mortality associated with AMI was mainly due to ventricular fibrillation (VF) before the establishment of the CCU, but CCU management corresponding to 24 h decreased arrhythmia deaths. Complications such as free wall rupture decreased due to reperfusion therapy and CCU care, and the mortality rate in the CCU has become less than 5% [2]. Meanwhile, in patients with medically complex conditions admitted to intensive care unit (ICU) or CCU, the ratio of acute coronary syndrome in ICU or CCU has decreased relatively [3]. Therefore, there is a recognition that ICU management is not necessary for AMI without complications [4], and cardiologists' care at all times has decreased [5,6]. In addition to cardiogenic shock due to AMI, there is an increase in other cardiovascular diseases including intractable heart failure accompanying multiple comorbidities. Thus, the CCU is forced to switch to cardiovascular intensive care (CICU), and cardiologists have

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realized change in line with ICU recent progress [7–9]. Along with the increase in the aging population, multiple organ failure due to coexistence of acute kidney injury, respiratory failure, and sepsis increases the number of procedures such as mechanical ventilation and bronchoscopy as compared to cardiovascular procedures, thus strategies for optimal training, staffing, and clinical investigation in the ICU are required [4,10,11].

In this review, I will present the achievements that CCU has achieved to date and discuss the future role that new critical cardiovascular care should play.

Advanced failing heart and treatments

AMI with cardiogenic shock occurs at a rate of 5–7%, the mortality remains high, from higher than 50% before the percutaneous coronary intervention (PCI) era to 40% after PCI-era [2,12–14]. If the shock is already prolonged at the time of hospitalization, even if a mechanical circulatory assistance device is deployed and early coronary revascularization is performed, patients die due to multiorgan failure [15]. In ST-elevation myocardial infarction (STEMI), it was revealed that the mortality rate is higher if the time from the first contact with medical staff to the reperfusion by catheterization is delayed. It was reported that the 3.3% mortality rate increases with each 10-min delay in cardiogenic shock [16]. Even in acute heart failure, the death rate increases as the time to hospitalization is delayed [17,18]. Severe acute heart failure including cardiogenic shock was reported to have resulted in deaths in the emergency room before entering the ICU [19]. Patients with acute heart failure and cardiogenic shock were quickly transported to an expert center before it became severe, then prepared for respiratory and circulation management before admission through the medical team that was familiar with rapid diagnosis and treatment [18,20]. For STEMI with cardiogenic shock, the 12-lead electrocardiogram and information on the severity are reported from the ambulance so that the catheterization room and percutaneous cardiopulmonary support (PCPS) and Impella (Abiomed, Danvers, MA, USA) [21] will be prepared [16,18].

Although it is necessary to use catecholamine for drug treatment of cardiogenic shock, it has been shown that the use of dopamine has increased the incidence of arrhythmia and the mortality rate is higher than that of noradrenaline. Therefore, the use of noradrenaline is recommended, even if a disadvantage of this is an increase in afterload [22,23]. The usefulness of a combination of dobutamine with inotropic action and vasodilating effect and noradrenaline was shown in comparison with adrenaline [24]. While observing the hemodynamics in the Swan-Gantz catheter and echocardiogram, it is important for the cardiovascular intensive care physician in the CICU to control the situation so that shock can be stabilized by using appropriate medications and circulatory support devices. At the same time, mechanical ventilation, renal replacement therapy, and infection control are also necessary, and integrated multidisciplinary care coordinated by skilled intensive care physicians, nurses, respiratory therapists, physiotherapists, pharmacists, nutritionists, social workers, and clinical engineers is important. Clinical studies aimed at establishing optimal treatment are necessary for cardiogenic shock [23].

In order to obtain the maximum effect in intensive care after the return of spontaneous circulation (ROSC), hemodynamic stabilization using PCPS, temperature management, coronary angiography, and PCI is recommended [25]. Three previous randomized trials and two observational studies about temperature management are shown (Fig. 1). The neurological good outcomes of the Hypothermia After Cardiac Arrest study group (HACA) trial [26] and the report of Bernard et al. [27] were 49% and 55%, respectively, which were significantly better than the control group. In addition, Sunde et al. showed a similar outcome of 56% in observational studies [28]. In the prospective registry J-PULSE-HYPO, therapeutic hypothermia showed a 64% neurological good outcome in patients with VF/ventricular tachycardia [29], which is higher than witnessed for VF in out-of-hospital cardiac arrest of 16% in the era before therapeutic hypothermia [30]. In a report from the Targeted Temperature Management (TTM) trial group in Europe, 939 patients with ROSC after cardiogenic out-of-hospital cardiac arrest were randomly divided into two groups of target body temperature 33 °C and 36 °C. There was no significant difference in the survival rate at the end of the study and 180 days of survival with good neurological function [31]. There are many unresolved issues such as induction timing, appropriate core body temperature, maintenance duration, and rewarming speed. It is important to establish and disseminate appropriate methods of intensive care, especially brain protection according to the severity of brain injury.

Patient safety and prevention of out-of-hospital and in-hospital cardiac arrest

The time from the onset of AMI to the cardiac arrest is concentrated within one hour. In addition, symptoms of angina as a prodromal symptom of AMI are seen in half, so early admission before the onset of AMI will prevent cardiac arrest and the onset of AMI. In order to promptly carry out PCI by a quick transfer to the specialist hospital after calling the emergency services, the 12-lead electrocardiogram can be installed in the ambulance and the information can be transmitted in advance. As a method of this

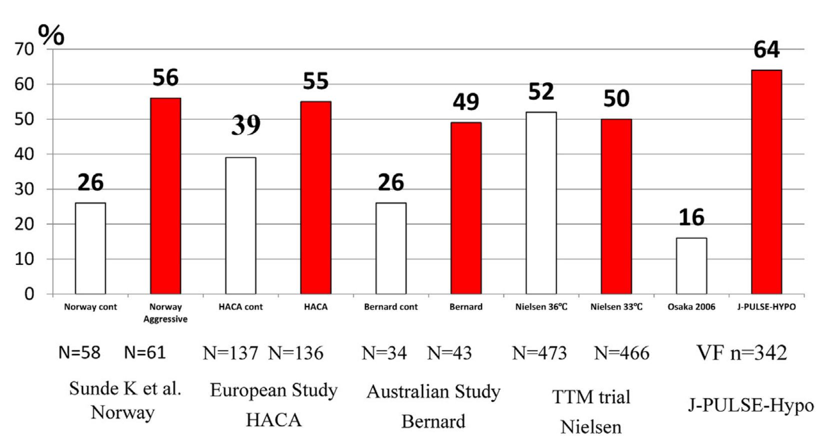

Fig. 1. Clinical studies in targeted temperature management for patients with return of spontaneous circulation (ROSC) after cardiac arrest. Red bars show the neurological good outcomes in targeted temperature management and white bars show those in controls. Study by Sunde et al. is an observational study [28], HACA study is a randomized controlled trial (RCT) [26], Bernard et al. is RCT [27], TTM trial is RCT [31], and J-PULSE-Hypo study is an observational study [29].

transmission, it is recommended that transmission by facsimile, use of automatic diagnostic equipment, Internet transmission by mobile telemedicine, or judgment by trained staff are recommended in the guidelines [25]. A network was constructed between the ambulance and the cardiologist in the CCU, and the hospital can prepare the catheter laboratory and the staff in advance according to the information before transfer. Then the time to PCI can be shortened by 20–30 min [25,32–34].

Unexpected cardiac arrest in the hospital occurred in various places including the intensive care unit and it was found that the survival discharge rate is low both in Japan and other countries [35,36]. To improve those situations, an emergency medical team capable of implementing rapid CPR and a rapid response team capable of determining severity beforehand are required [37]. Cardiovascular and intensive care physicians need to promote the medical team and training of the corresponding team is also necessary [38,39].

Training programs in cardiovascular critical care

For rapid and safe team medical practice, a standard training method is necessary.

One of the team leaders should be a cardiologist at CICU and it is necessary to become familiar with the method of protection of the myocardium and brain as well as the stability of hemodynamics. Team training and an implementation manual are necessary to carry out team medical care quickly and safely [40]. Therefore, in order to disseminate awareness of team medical care after ROSC, training texts were published by the Committee for the Emergency Cardiovascular Medicine of the Japanese Circulation Society and the Japan Resuscitation Council [41]. A practical training course for post ROSC care is being implemented (Table 1). This course includes various airway managements, reading of electroencephalogram, how to take a neurological physical finding, how to observe the pupil, PCPS cannulas insertion method using Endo-Circuit [42], learning priming of PCPS, various equipment for temperature management, team resuscitation in the simulation from VF to ROSC, and simulation of e-CPR to sustained VF. As described above, intensive care after ROSC progressed from conventional CCU to CICU including hemofiltration and various respiratory management techniques [8].

Table 1
Training course agenda for postcardiac arrest syndrome (PCAS).

Start	Finish		Contents
9:00	9:15	Reception	
9:15	9:20	Introduction	Course introduction
9:20	9:30	Lecture	Orientation
9:30	9:35	Pause	Break
9:35	10:05	Skill 1	Airway management in PCAS
10:05	10:35	Skill 2	Brain monitoring
10:35	11:05	Skill 3	Neurological physical examination
11:05	11:45	Lecture	Neurocritical care
11:45	11:55	Pause	Break
11:55	12:45	Skill 4	PCPS, IABP
12:45	12:55	Pause	Break
12:55	13:45	Skill 5	TTM
13:45	13:55	Pause	Break
13:55	14:45	Skill 6	Simulation: VF→PCAS
14:45	14:55	Pause	Break
14:55	15:10	Debriefing	Debriefing for simulation training
15:10	15:15	Pause	Break
15:15	16:10	Skill 7	Simulation: VF(ECPR)
16:10	16:20	Summary	Course conclusion

ECPR, extracorporeal cardiopulmonary resuscitation; IABP, intra-aortic balloon pumping; PCPS, percutaneous cardiopulmonary support; TTM, targeted temperature management; VF, ventricular fibrillation.

Severity scores for cardiovascular diseases in CICU

The European Society of Intensive Care Medicine revised the consensus on shock [43]. Of the cases admitted to the ICU, shock accounted for 1/3, of which 62% of sepsis, 17% of cardiogenic, and 16% of hypovolemia, thus sepsis increased and cardiovascular disease is relatively decreased. Even in cardiovascular diseases, many cases are complicated by multiple organ failure, and elderly heart failure is increased. ICU has been changed from the CCU to advanced cardiac intensive care unit [3], cardiovascular intensive care unit [8,44,45], or intensive cardiac care unit [46], which deal with cardiovascular diseases and respond to multiple organ failure management by multiple medical teams including various field physicians. In such circumstances, several scores for predicting the outcome of severe cases have been proposed and shifting to lifesaving for more severe cases in ICU.

For severity score of AMI, Killip classification and Forrester classification were established 50 years ago [47]. The outcome of AMI is improved in CCU with reperfusion therapy, and the mortality rate at CCU has become less than 5% [14]. However, the mortality rate of Killip 4 (cardiogenic shock) is still high at around 50% [48]. The circulatory management for cardiogenic shock is an important issue of the present CCU, therefore, appropriate risk stratification models to optimize patient selection for CICU admission and to predict adverse outcomes are needed.

Definition of shock is when systolic blood pressure less than 90 mmHg or vasopressors are required to maintain 90 mmHg in the absence of hypovolemia with systemic tissue hypoperfusion. Using the mean arterial pressure as the organ perfusion pressure, shock is defined as less than 65 mmHg especially for septic shock [43]. As a definition of cardiogenic shock, it seems appropriate to use systolic blood pressure in considering contractile force and afterload. However, since blood pressure is compensated by vasoconstriction, blood pressure may be maintained even with systemic tissue hypoperfusion [43]. Systemic tissue hypoperfusion is due to abnormal tissue perfusion and oxygenation, which is accompanied by cold sweats, confusion, and oliguria. This state is also combined with serum lactate value (2 nmol/L or more) and central venous saturation less than 70% of the central vein [18,43,49]. Various scores have been reported for evaluating the severity of shock. The Sequential Organ Failure Assessment (SOFA) score used in sepsis is evaluated with a 4-point assessment of organ dysfunction (respiration, coagulation, liver, cardiovascular, central nervous system, and kidney). The mortality prediction in the CICU showed more than the first-day SOFA score of 5 points or more, and the hospital mortality of 24.5% and 3.1% at less than 5 points [50]. The SOFA score was reported to be useful for assessing the severity of out-of-hospital cardiac arrest with ROSC [51]. In addition, there are APACHE (Acute Physiology and Chronic Health Evaluation), Elebute-Stoner, SAPS II (Simplified Acute Physiology Score). APACHE is mainly used for trauma, abdominal complications, chronic obstructive pulmonary disease, acute pancreatitis, or sepsis. It was not originally a severity assessment of cardiovascular disease. There are reports that these evaluation methods were applied to the cardiogenic shock of AMI [52]. The mortality rate of 45 patients with cardiogenic shock was 44%, and APACHE II, III, SAPS II were able to predict survival significantly with each score. With these scores, the GCS score is used for brain functional evaluation, and it is difficult to evaluate if tracheal intubation or sedation is performed [53].

For risk assessment of non-ST elevation acute coronary syndrome, Braunwald score and thrombolysis in myocardial infarction (TIMI) risk score are used, however, it is not suitable for severity assessment on the cardiogenic shock. The mortality prediction score used in the IABP – SHOCK II trial was considered to be convenient and useful for stratification [54,55]. However, this

Table 2
GRACE score.

Killip class	Points	SBP (mmHg)	Points	HR (bpm)	Points	Age	Points	Creatinine (mg/dL)	Points	Other risk factors	Points
I	0	≤80	58	≤50	0	≤30	0	0–0.39	1	Cardiac arrest admission	39
II	20	80–99	53	50–69	3	30–39	8	0.4–0.79	4	ST-segment deviation	28
III	39	100–119	43	70–89	9	40–49	25	0.8–1.19	7	Elevated cardiac enzyme levels	14
IV	59	120–139	34	90–109	15	50–59	41	1.2–1.59	10		
		140–159	24	110–149	24	60–69	58	1.6–1.99	13		
		160–199	10	150–199	38	70–79	75	2.0–3.99	21		
		≥200	0	≥200	46	80–89	91	≥4.0	28		
						≥90	100				

GRACE score, Global Registry of Acute Coronary Events score [55]; HR, heart rate; SBP, systolic blood pressure.

Table 3
Severity score in intensive care unit medical fee version 2016 by the Japanese Ministry of Health, Labor and Welfare.

	No	Yes
ECG monitoring	0	1
Transfusion pump	0	1
Syringe pump	0	1
Invasive blood pressure	0	2
Central venous pressure	0	2
Respirator	0	2
Blood transfusion	0	2
Swan-Gantz catheter	0	2
Invasive treatments (CHDF, IABP, PCPS, ventricular assist device, ICP)	0	2

CHDF, continuous hemodiafiltration; ECG, electrocardiogram; ICP, intracranial pressure; IABP, intra-aortic balloon pumping; PCPS, percutaneous cardiopulmonary support.

score needs TIMI blood flow evaluation after PCI, so it is a difficulty to be limited to the PCI implementation in acute coronary syndrome. There is GRACE risk score including Killip classification [56–58]. This is applicable to all cases of acute coronary syndrome including Killip classification (type 4, 59 points), systolic blood pressure (58 points below 80 mmHg), pulse rate (from 200 bpm to 46 points), age (90–100 points), creatinine (4 above 28 points). The maximum mortality rate is 291 points and the estimated mortality rate becomes 52% or more [56] (Table 2). It is reported that more than 140 GRACE scores are independent mortality predictors in Japan [57]. Likewise, the 2015 acute coronary syndrome guidelines of the European Society of Cardiology [59] also suggest non-ST elevated acute coronary syndrome and early invasive treatment with GRACE 140 or higher, so the GRACE score, which is reasonable for intensive care management, is considered to be 140 or more. There are reports that the GRACE score is useful for outcome prediction after ROSC in out-of-hospital cardiac arrest [60]. When the septic shock is divided into 4 by lactic acid value for the early determination of organ failure, the mortality rate significantly increases when it is higher than 1.4 nmol/L [61]. European Society of Intensive Care recommends 2 nmol/L or more is used as a cut-off value for shock [43]. In the case of AMI with Killip II and III lactic acid value of 2.5 nmol/L or more, the mortality rate was higher than 28% and 5% lower than 2.5 [62].

In addition, it has been pointed out that the high value of B-type natriuretic peptide (BNP), a biochemical marker, correlates with mortality [18,63]. A cut-off value of the poor outcome of BNP at

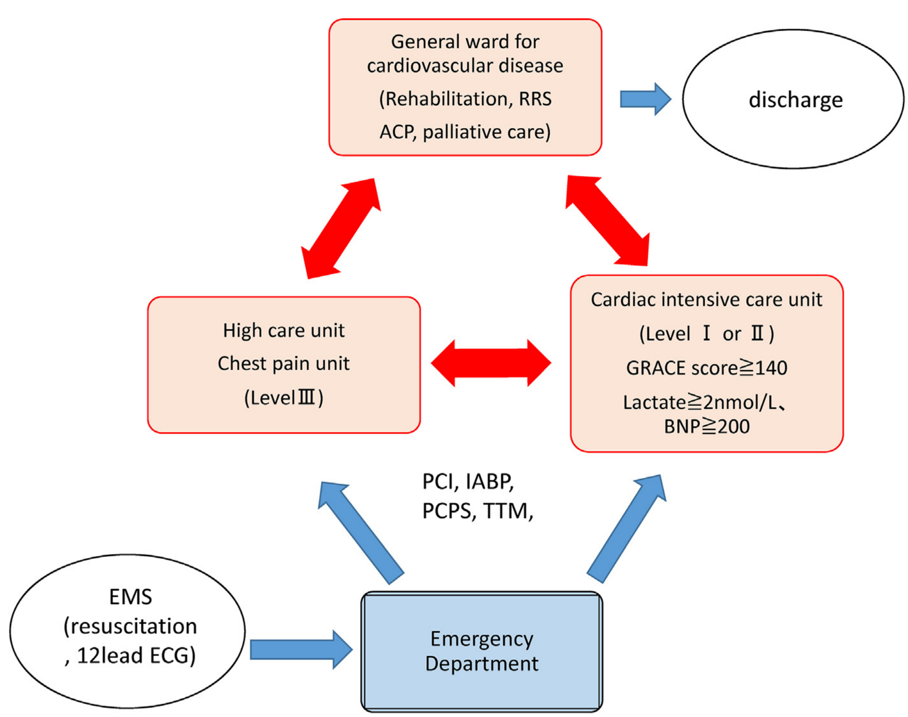

Fig. 2. Flow chart for cardiovascular critical care. ACP, advanced care planning; BNP, B-type natriuretic peptide; ECG, electrocardiogram; EMS, emergency medical system; GRACE, Global Registry of Acute Coronary Events; IABP, intra-aortic balloon pumping; RRS, rapid response system; PCPS, percutaneous cardiopulmonary support; PCI, percutaneous coronary intervention; TTM, targeted temperature management.

hospitalization is 80–100 pg/mL [64–66]. The outcome prediction becomes good with the combination of GRACE score and BNP [64], and no change in another report [67]. It is necessary to select cardiovascular cases to admit to CICU by using these blood markers in combination with the GRACE score, which is a gap to be solved in the future.

Can low-risk acute coronary syndromes be admitted to CICU?

Unlike in the USA, the number of ICU beds in Japan is limited. In order to effectively utilize the currently limited bed numbers, it is necessary to decide whether to admit patients for cardiovascular intensive care treatment by the evaluation method predicting the severity and the possibility of deterioration. The guidelines for severity and the nursing necessity for specific ICU were revised in 2016 Japan. The use of electrocardiogram monitoring, infusion pump, or management using microparts for infusion using syringe pump are indispensable for circulation management, however, those are only one point each. On the contrary, two points are given to special treatments such as invasive blood pressure monitoring, mechanical ventilation, transfusion management, or extracorporeal circulation (Table 3). An acute coronary syndrome that is an intrinsically high risk is difficult to admit to ICU or CCU when there is no complication of hospitalization.

In 2012, the American Heart Association CICU statement proposed a categorization of CICU classified into three levels; level I being the highest to level III as the lowest category [8]. In order to promptly implement rapid prevention and treatment after hospitalization, as shown in Fig. 2, a patient considered to be mild is to enter an observation unit such as a cardiovascular high care unit corresponding to a short-term level III. It is judged by GRADE score of 140 points or more, lactic acid value or BNP high value, and it is necessary to accommodate in CICU level I or II.

Team medical practice and training system that can maximize the power of a cardiologist, cardiac surgeon, an intensive care physician, emergency physician, and nurse are needed. The effectiveness of dedicated intensive care physicians always working at CICU has already been demonstrated [11,68].

In the future CICU in Japan will respond to changes in the disease structure and super aging era, technical innovation in medical team and training of CICU-based cardiologists will be reconstructed, and the high-intensity and high-quality cardiac critical care suitable for the medical situation in Japan will be restructured.

Conflicts of interest

The author has no funding and conflict of interest for this article.

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