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Clinical paper

Mechanical chest compression increases intrathoracic hemorrhage complications in patients receiving extracorporeal cardiopulmonary resuscitation

Yoshihisa Matsushima[a,b], *Tatsuhiro Shibata*[a,c,*], *Kodai Shibao*[a], *Rei Yamakawa*[a,b], *Miyu Hayashida*[a,b], *Toshiyuki Yanai*[a,b], *Takashi Ishimatsu*[a,b], *Takehiro Homma*[a], *Shoichiro Nohara*[a,b], *Maki Otsuka*[a,b], *Yoshihiro Fukumoto*[a]

Abstract

Background: Mechanical cardiopulmonary resuscitation (CPR) devices address the limitations of manual CPR, but their impact on intrathoracic injuries during extracorporeal CPR (ECPR) remains unclear. This study investigated the relationship between mechanical CPR and severe intrathoracic hemorrhage during ECPR compared to manual CPR.

Methods: We conducted a single-center retrospective study of consecutive patients who underwent ECPR from April 2017 to March 2024 according to a standard institutional protocol. Patients were divided into a mechanical CPR group (piston-driven compressions before veno-arterial extracorporeal membrane oxygenation [VA-ECMO]) and a manual CPR group. The primary outcome was intrathoracic hemorrhage requiring transcatheter arterial embolization (TAE). Secondary outcomes included other intrathoracic injuries and 180-day survival.

Results: A total of 91 patients were enrolled (mechanical $n = 48$, manual $n = 43$). Intrathoracic hemorrhage requiring TAE occurred more frequently in the mechanical CPR group (18.8% vs. 2.3%, $p = 0.030$). On multivariate analysis, mechanical CPR was independently associated with this outcome (adjusted odds ratio 6.29; 95% confidence interval 1.20–65.10). In the mechanical group, older age and larger thoracic transverse diameter were significantly related to intrathoracic hemorrhage requiring TAE. Mediastinal hematoma (18.8% vs. 2.3%, $p = 0.030$) and hemothorax (20.8% vs. 4.7%, $p = 0.049$) were also more frequent in the mechanical group. The 180-day survival rates did not differ significantly between groups (27.7% vs. 25.0%, log-rank $p = 0.540$).

Conclusions: Mechanical CPR during ECPR is associated with an increased risk of severe intrathoracic hemorrhage. While mechanical CPR devices may provide benefits in certain scenarios, clinicians should carefully consider individual patient characteristics and closely monitor for complications.

Keywords: Cardiopulmonary resuscitation, Thoracic injury, Chest compression, Mechanical chest compression device, Intrathoracic hemorrhage, Extracorporeal cardiopulmonary resuscitation

Introduction

In-hospital cardiac arrest (IHCA) and out-of-hospital cardiac arrest (OHCA) remain significant challenges in modern healthcare.[1,2] Chest compression has long been recognized as the cornerstone of cardiopulmonary resuscitation (CPR), and its importance has become increasingly evident in recent years.[3] Moreover, there has been a growing emphasis on the quality of chest compressions. Several critical factors for effective chest compressions include maintain-

Abbreviations: BSA, Body surface area, CI, Confidence interval, CPR, Cardiopulmonary resuscitation, CT, Computed tomography, ECPR, Extracorporeal cardiopulmonary resuscitation, EMS, Emergency medical services, IHCA, In-hospital cardiac arrest, IPTW, Inverse probability of treatment weighting, OHCA, Out-of-hospital cardiac arrest, OR, Odds ratio, ROSC, Return of spontaneous circulation, SD, Standard deviation, TAE, Transcatheter arterial embolization, VA-ECMO, Veno-arterial extracorporeal membrane oxygenation

* Corresponding author at: Division of Cardiovascular Medicine, Department of Internal Medicine, Kurume University School of Medicine 67 Asahi-machi, Kurume 830-0011, Japan.

E-mail address: tatsuhiro_shibata@kurume-u.ac.jp (T. Shibata).

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ing continuous compressions with minimal interruptions, ensuring an appropriate rate and depth, avoiding leaning on the chest between compressions, and preventing excessive ventilation.[4]

Manual CPR has been the standard of care for decades but is subject to fatigue and variability in the quality of chest compressions.[5] Mechanical CPR devices have recently been developed to address these limitations by offering consistent and uninterrupted compressions.[6] Previous studies have also reported that mechanical CPR, particularly piston-driven systems, does not cause significantly more severe or life-threatening internal injuries than manual CPR.[7] The use of mechanical CPR has been increasing among certain healthcare providers and systems, particularly in scenarios with limited personnel or during patient transport, where safety concerns are prominent.[3] However, despite these potential advantages, studies comparing mechanical CPR devices with manual CPR have not demonstrated the superiority of these devices.[8–11]

Extracorporeal cardiopulmonary resuscitation (ECPR) with venoarterial extracorporeal membrane oxygenation (VA-ECMO) has been proposed as a potential life-saving option for refractory cardiac arrest in well-equipped healthcare systems with trained staff.[12–14] While mechanical CPR devices can provide consistent chest compressions during ECPR implementation, their specific effects in the context of ECPR remain poorly understood.[15] Particularly, the potential complications of mechanical CPR use during ECPR, such as intrathoracic injuries, have not been thoroughly explored.

We hypothesized that the use of mechanical CPR devices during ECPR might be associated with an increased risk of intrathoracic complications compared with manual CPR. The primary objective of this study was to evaluate the association between mechanical CPR and severe intrathoracic hemorrhage requiring transcatheter arterial embolization (TAE) during ECPR compared to manual CPR. In addition, we aimed to investigate other intrathoracic injuries and examine their impact on short-term survival.

Methods

Study design

This single-center, retrospective cohort study examined all consecutive patients with IHCA or OHCA who underwent ECPR within 24 h of admission between April 2017 and March 2024. Mechanical CPR devices were introduced in the emergency department of our hospital in April 2022 and were actively used for patients with cardiac arrest until June 2023. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki and approved by the Ethics Committee of Kurume University Hospital (approval number 23187). Informed consent was obtained through an opt-out format on the hospital's website.

Study population

In the present study, ECPR was defined as the insertion of VA-ECMO for refractory cardiac arrest lasting more than 15 minutes[16] or VA-ECMO insertion within 20 min after the return of spontaneous circulation (ROSC) due to hemodynamic instability.[17] This study included both IHCA and OHCA patients. ECPR was performed according to our ECPR criteria (described later). We excluded patients who did not undergo computed tomography (CT) after VA-ECMO establishment, those whose CPR method was not documented, those under 18 years of age, and those who did not receive ECPR within 24 h of admission.

Procedures

The manual chest compression group (manual CPR group) was defined as those who received consistent manual chest compressions until the initiation of VA-ECMO. The piston-driven mechanical chest compression device group (mechanical CPR group) initially received manual chest compressions from witnesses or medical staff at the site of detection, which were then immediately switched to mechanical chest compressions upon arrival at the emergency room, followed by VA-ECMO insertion. The mechanical chest compression devices used were LUCAS 3 (Physio-Control/Jolife AB, Lund, Sweden), Clover 3000 (Kohken Medical, Tokyo, Japan), or Corpuls (GS Elektromedizinische Geräte/G. Stemple GmbH; Kaufer, Germany). Each mechanical chest compression device was configured according to the Japan Resuscitation Council Guidelines 2020, with a chest compression depth of 5–6 cm chest compression depth.[18,19] The mechanical CPR group also included patients in whom mechanical chest compressions were initiated in a prehospital setting. This is possible because some local emergency medical services (EMS) are equipped with mechanical chest compression devices, specifically the Clover 3000. In these instances, the Clover3000 was used continuously from the field until hospital arrival, and the device continued to be used or was switched to an in-hospital mechanical chest compression device upon arrival.

We previously reported our institution's ECPR criteria and VA-ECMO management procedure.[20] The eligibility criteria for ECPR were as follows: (1) patients with functional independence; (2) patients accessible within 45 min of cardiopulmonary arrest; (3) patients without echocardiographic evidence of pericardial effusion or aortic dissection; and (4) age of less than 75 years for patients with shockable rhythms, and less than 70 years for those with non-shockable rhythms. The indications for ECPR were determined according to this protocol. However, in cases where detailed patient information, such as age and underlying diseases, was unavailable before ECPR or in cases of IHCA, the indications were expanded based on the clinical judgment of multiple emergency cardiologists.

Data collection

We collected the following data from medical records: age, sex, height, weight, body surface area (BSA), medical history, cause of cardiac arrest, presence of bystander CPR, initial rhythm, low flow time, total arrest time, and the type of mechanical circulatory support device used. Low flow time was defined as the total duration of chest compressions, which continued uninterrupted from initial resuscitation until ECMO establishment. Laboratory data were collected after VA-ECMO insertion. All enrolled patients underwent CT after VA-ECMO insertion to evaluate intrathoracic hemorrhage, mediastinal hematoma, pneumothorax, hemothorax, and cardiac tamponade. Intrathoracic hemorrhage was defined as contrast extravasation into the chest cavity on contrast-enhanced CT or angiography. Mediastinal hematoma and pneumothorax were definitively diagnosed using CT. Cardiac tamponade was defined as pericardial fluid accumulation on CT or echocardiography, requiring immediate drainage. Hemothorax was defined as hemorrhagic fluid accumulation on CT based on clinical judgment, hemorrhagic drainage from an inserted chest tube, or hemorrhagic fluid accumulation detected at autopsy. Additionally, we measured the transverse and longitudinal thoracic diameters at the level of the sternal attachment of the 5th rib on axial CT images. The transverse diameter was defined as the distance between the outer edges of the ribs at that level, whereas the longitudinal diameter (anteroposterior dimension) was measured from the superior margin of the sternum to the inferior margin of the corresponding vertebral body on the same slice. Multiple board-certified cardiologists used a standardized data dictionary to review charts, resolving ambiguities by consensus. They were independent from the analysis team, and a separate analyst cleaned the data to ensure accuracy.

Clinical outcomes

The primary outcome was intrathoracic hemorrhage requiring TAE. Secondary outcomes included other intrathoracic injuries such as mediastinal hematoma, pneumothorax, hemothorax, and cardiac tamponade, as well as 180-day survival.

Statistical analysis

This study included all eligible patients during the specified period, prioritizing the maximum sample size over a priori power calculations to enhance estimation precision. We implemented several strategies to address potential biases in this retrospective study, including standardized data collection, multivariate analyses, and sensitivity analyses. We addressed 6.3% of the missing data for BSA using multiple imputations by chained equations with predictive mean matching. Five imputed datasets were generated. Analyses were performed separately on each imputed dataset, and the results were combined using Rubin's rules to account for imputation uncertainty. Imputation variables included age, sex, weight, and height. Patient characteristics are summarized using means and standard deviations (SD) for continuous variables and frequencies and percentages for categorical variables. Patients were stratified into manual and mechanical CPR groups, and baseline characteristics were compared between these groups. We also compared IHCA and OHCA in a supplemental sub-analysis. We used chi-squared or Fisher's exact tests for categorical variables and t-tests for continuous variables, as appropriate. We examined the association between each variable and the primary endpoint using univariate and multivariate Firth penalized logistic regression models. Odds ratios (OR) with 95% confidence intervals (CI) were reported. Variables for the multivariable model were selected based on clinical relevance and prior knowledge, regardless of their statistical significance in the univariate analyses. The final model incorporated age, mechanical CPR (vs. manual CPR), and thoracic transverse diameter. We performed an inverse probability of treatment weighting (IPTW) analysis for sensitivity analysis. Propensity scores were estimated using logistic regression, with age, sex, BSA, acute coronary syndrome, low flow time, and thoracic transverse diameter as predictors. We assessed the balance of covariates after IPTW using standardized mean differences, considering values less than 0.1 to indicate a good balance.

Additionally, we performed a subgroup analysis to explore outcome-related factors within the mechanical CPR group using univariate and multivariate Firth's penalized logistic regressions. We conducted survival analysis using Kaplan-Meier curves and log-rank tests to compare 180-day survival between the mechanical and manual CPR groups. All statistical tests were two-tailed, and p values <0.05 statistically significant. All statistical analyses were performed using R version 4.4.0 (The R Foundation for Statistical Computing, Vienna, Austria).

Results

Patient characteristics

During the study period, 96 patients underwent ECPR at our hospital. We excluded two patients with unclear CPR method records, one patient without CT imaging after VA-ECMO establishment, one patient under 18 years of age, and one patient who received ECPR more than 24 h after admission. Finally, 91 patients were included in this study (59.6 ± 13.5 years, 89% male), with 43 (47.3%) in the manual CPR group and 48 (52.7%) in the mechanical CPR group (Fig. 1). In the mechanical CPR group, LUCAS 3 was used in 43 cases, CLOVER 3000 in 3 cases, and Corpulse in 1 case. In one case, the CLOVER 3000 was used by the EMS in the pre-hospital setting and then switched to LUCAS 3 upon arrival at our hospital. Table 1 shows the characteristics of the study participants. The mechanical CPR group showed a significantly lower BSA than the manual CPR group (1.75 ± 0.17 vs. 1.84 ± 0.17, p = 0.018), but there were no differences in medical history, acute coronary syndrome rate, OHCA ratio, total arrest time, low flow time, pH, and lactate level. A comparison of IHCA and OHCA cases revealed similar baseline characteristics and low flow times between groups (Supplemental Table 1 and Supplemental Figure), with differences observed only in bystander CPR rates and initial shockable rhythms.

Clinical outcomes

Analysis of the primary outcome demonstrated that severe intrathoracic hemorrhage requiring TAE occurred significantly more frequently in the mechanical CPR group than in the manual CPR group (9 cases [18.8%] vs. 1 case [2.3%], p = 0.030) (Table 2). Among the secondary outcomes, mediastinal hematoma and hemothorax were also significantly more common in the mechanical CPR group (9 [18.8%] vs. 1 [2.3%], p = 0.030, and 10 [20.8%] vs. 2 [4.7%], p = 0.049, respectively). In a supplemental subgroup comparison of IHCA and OHCA ((Supplemental Table 2), the incidence of primary outcome was not significantly different. In the univariate analysis of factors associated with the primary outcome, age (OR: 1.08 [95%CI: 1.01–1.16], p = 0.019), mechanical CPR (OR: 6.81 [95%CI: 1.47–65.60], p = 0.012), and thoracic transverse diameter (OR: 1.85 [95%CI: 1.13–3.41], p = 0.013) showed significant associations (Table 3). These associations remained significant after multivariate adjustment, with age (OR: 1.09 [95%CI: 1.02–1.20], p = 0.015) and mechanical CPR (OR: 6.29 [95%CI: 1.20–65.10], p = 0.029) emerging as independent risk factors (Table 3). The IPTW analysis further confirmed the strong association between mechanical CPR and intrathoracic hemorrhage requiring TAE (OR 10.57 [95%CI: 2.85–71.59], p < 0.001).

Further analysis within the mechanical CPR group revealed that both age (OR: 1.09 [95%CI: 1.02–1.22], p = 0.016) and thoracic transverse diameter (OR: 1.91 [95%CI: 1.09–4.02], p = 0.021) were significantly associated with the primary outcome (Table 4). These associations persisted after multivariate adjustment, with age (OR: 1.08 [95%CI: 1.01–1.21], p = 0.030) and thoracic transverse diameter (OR: 1.86 [95%CI: 1.05–4.28], p = 0.032) remaining significant predictors (Table 4). Kaplan-Meier analysis of 180-day survival showed no significant difference between the groups (log-rank p = 0.540), with survival rates of 25.0% and 27.7% in the manual and mechanical CPR groups, respectively (Fig. 2).

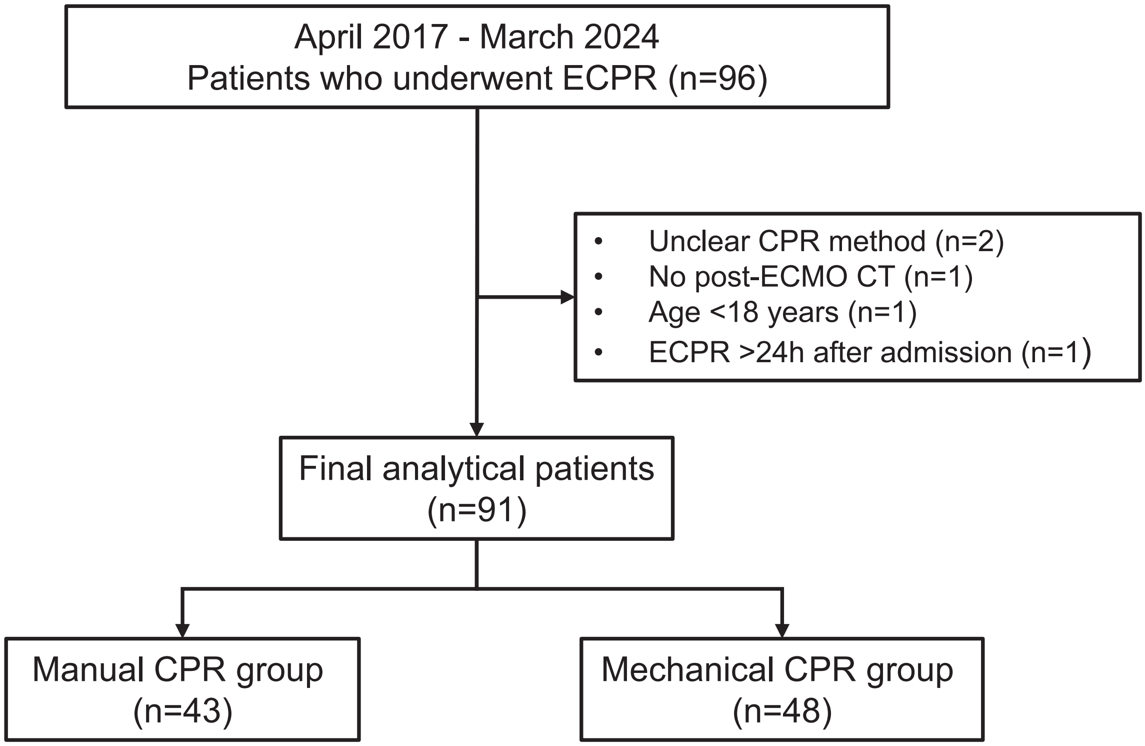

Fig. 1 – Study flow diagram. CPR, cardiopulmonary resuscitation; CT, computed tomography; ECMO, extracorporeal membrane oxygenation; ECPR, extracorporeal cardiopulmonary resuscitation.

Table 1 – Baseline characteristics of study patients.

	All (*n* = 91)	Manual CPR (*n* = 43)	Mechanical CPR (*n* = 48)	*p*-value
Age, y	59.6 ± 13.5	60.6 ± 12.3	58.6 ± 14.6	0.488
Male	81 (89.0)	38 (88.4)	43 (89.6)	1.000
BSA, m^2 (missing 6)	1.80 ± 0.17	1.75 ± 0.17	1.84 ± 0.17	0.018
Past medical history				
Hypertension	49 (53.8)	23 (53.5)	26 (54.2)	1.000
Diabetes	31 (34.1)	17 (39.5)	14 (29.2)	0.412
Chronic heart failure	13 (14.3)	8 (18.6)	5 (10.4)	0.415
Coronary heart disease	19 (20.9)	8 (18.6)	11 (22.9)	0.805
Atrial fibrillation	10 (11.0)	5 (11.6)	5 (10.4)	1.000
Hemodialysis	3 (3.3)	1 (2.3)	2 (4.2)	1.000
Acute coronary syndrome	54 (59.3)	23 (53.5)	31 (64.6)	0.389
OHCA	62 (68.1)	29 (67.4)	33 (68.8)	1.000
Bystander CPR	80 (87.9)	36 (83.7)	44 (91.7)	0.402
Shockable rhythm	68 (74.7)	32 (74.4)	36 (75.0)	1.000
Total arrest time, min	49.0 ± 20.5	46.1 ± 22.1	51.6 ± 18.9	0.202
Low flow time, min	44.8 ± 19.6	42.1 ± 21.1	47.3 ± 18.2	0.207
Mechanical CPR time, min	17.5 ± 9.0	NA	17.5 ± 9.0	NA
Laboratory data just after ECPR				
pH	6.98 ± 0.19	6.98 ± 0.20	6.98 ± 0.19	0.941
Lactate, mmol/L	13.5 ± 5.4	13.0 ± 5.6	14.0 ± 5.2	0.377
eGFR, mL/min/1.73 m^2	50.9 ± 19.4	53.4 ± 18.4	48.6 ± 20.2	0.242
Hemoglobin, g/dL	11.9 ± 2.1	12.1 ± 2.0	11.7 ± 2.1	0.278
Platelets, $\times 10^4$/ul	15.7 ± 9.6	14.5 ± 6.3	16.7 ± 11.8	0.288

Data are presented as mean ± standard deviation and *n* (%) for categorical measures.

BSA, body surface area; CPR, cardiopulmonary resuscitation; ECPR, extracorporeal cardiopulmonary resuscitation; eGFR, estimated glomerular filtration rate; and OHCA, out-of-hospital cardiac arrest.

Table 2 – Serious or life-threatening chest compression-related complications.

	Manual CPR (*n* = 43)	Mechanical CPR (*n* = 48)	*p*-value
Intrathoracic bleeding requiring TAE	1 (2.3)	9 (18.8)	0.030
Internal thoracic artery bleeding	0 (0.0)	9 (18.8)	0.008
Lateral thoracic artery bleeding	1 (2.3)	1 (2.1)	1.000
Mediastinal hematoma	1 (2.3)	9 (18.8)	0.030
Pneumothorax	0 (0.0)	2 (4.2)	0.524
Hemothorax	2 (4.7)	10 (20.8)	0.049
Cardiac tamponade	1 (2.3)	5 (10.4)	0.259

Data are presented as *n* (%).

CPR, cardiopulmonary resuscitation; TAE, transcatheter arterial embolization.

Table 3 – Univariate and multivariable models for analysis of severe intrathoracic hemorrhage requiring transcatheter arterial embolization.

Variables	Univariate model		Multivariable model	
	OR (95%CI)	*p*	OR (95%CI)	*p*
Age, y	1.08 (1.01–1.16)	0.019	1.09 (1.02–1.20)	0.015
Male	3.08 (0.25–407.00)	0.376		
BSA (per SD)	1.35 (0.70–2.67)	0.375		
Low flow time, per min	1.00 (0.96–1.03)	0.932		
Mechanical CPR (vs. manual CPR)	6.81 (1.47–65.6)	0.012	6.29 (1.20–65.10)	0.029
Shockable rhythm (vs. non-shockable rhythm)	2.39 (0.51–23.20)	0.407		
OHCA (vs. IHCA)	3.37 (0.72–32.60)	0.133		
Longitudinal diameter of thorax, per cm	0.82 (0.52–1.30)	0.394		
Transverse diameter of thorax, per cm	1.85 (1.13–3.41)	0.013	1.56 (0.98–2.85)	0.061
Antithrombotic medication	1.23 (0.32–4.41)	0.751		
Acute coronary syndrome	1.56 (0.43–6.79)	0.510		

BSA, body surface area; CI, confidence interval; CPR, cardiopulmonary resuscitation; IHCA, in-hospital cardiac arrest; OHCA, out-of-hospital cardiac arrest; OR, odds ratio; and SD, standard deviation.

Table 4 – Models for analysis of severe intrathoracic hemorrhage requiring transcatheter arterial embolization in Mechanical CPR patients.

Variables	Univariate model		Multivariable model	
	OR (95%CI)	*p*	OR (95%CI)	*p*
Age, y	1.09 (1.02–1.22)	0.016	1.08 (1.01–1.21)	0.030
Male	3.03 (0.30–411.00)	0.406		
BSA, per SD	1.30 (0.63–2.86)	0.480		
Low flow time, per min	0.98 (0.93–1.02)	0.409		
Mechanical CPR time, per min	0.96 (0.85–1.05)	0.444	0.94 (0.80–1.04)	0.274
Longitudinal diameter of thorax, per cm	0.85 (0.51–1.36)	0.486		
Transverse diameter of thorax, per cm	1.91 (1.09–4.02)	0.021	1.86 (1.05–4.28)	0.032
PCI within 3 h before and after ECPR	2.16 (0.53–10.20)	0.286		
Acute coronary syndrome	1.90 (0.44–11.20)	0.408		
IMPELLA	3.49 (0.81–20.5)	0.149		

BSA, body surface area; CI, confidence interval; CPR, cardiopulmonary resuscitation; ECPR, extracorporeal cardiopulmonary resuscitation; OR, odds ratio; PCI, percutaneous coronary intervention; and SD, standard deviation.

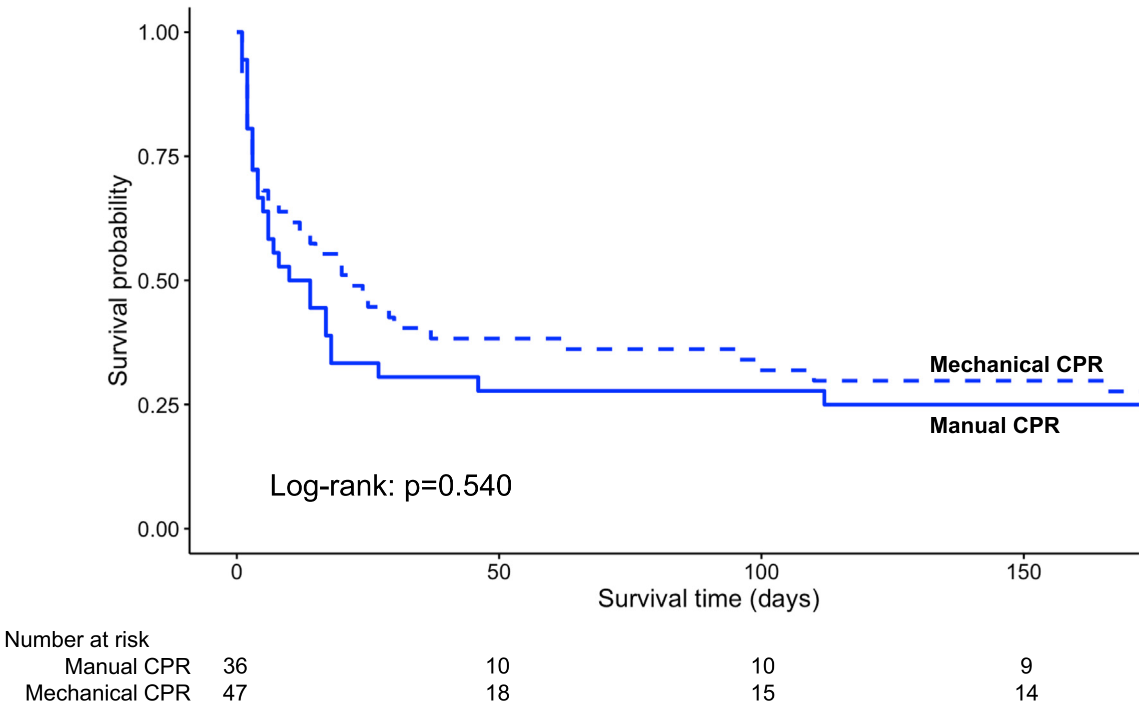

Fig. 2 – Cumulative probability of survival: Manual CPR versus Mechanical CPR. Kaplan-Meier curves show the cumulative incidence of all-cause mortality for each CPR method. Solid and dotted lines represent the Manual and Mechanical CPR groups, respectively. CPR, cardiopulmonary resuscitation.

Discussion

Our findings demonstrated three key observations regarding mechanical CPR during ECPR. First, mechanical CPR was significantly associated with an increased odds of intrathoracic hemorrhage requiring TAE compared with manual CPR, and this association persisted after adjusting for confounding factors, as well as in our IPTW analysis. Second, age and thoracic transverse diameter were significantly associated with this complication, particularly in the mechanical CPR group. Third, although intrathoracic hemorrhage requiring TAE was more frequent in the mechanical CPR group, we observed comparable 180-day survival rates between the mechanical and manual CPR groups.

To the best of our knowledge, this is the first study to comprehensively examine and quantify the specific risk of intrathoracic hemorrhage requiring TAE associated with mechanical CPR in the context of ECPR. Intrathoracic trauma associated with CPR is frequently observed and may become more evident during ECPR because of two factors: (1) VA-ECMO prolongs survival, enabling the detection of underlying injuries; and (2) VA-ECMO necessitates anticoagulation, potentially aggravating traumatic hemorrhage.[21–24] Gaisendrees et al.[25] reported that in patients who underwent ECPR, major hemorrhage was more common in the mechanical CPR group than in the manual CPR group. In our study, we quantified this risk more accurately and showed that mechanical CPR was significantly associated with higher odds of intrathoracic hemorrhage requiring TAE. Notably, there was no significant difference in survival between the mechanical and manual CPR groups in both studies,[25] suggesting that mechanical CPR may still play an essential role in specific ECPR scenarios despite the increased risk of certain complications.

Our analysis of the mechanical CPR group also identified age and thoracic transverse diameter as significant risk factors, providing additional insights that were not explored in a previous study. A previous Japanese study reported that older age and longer chest compression duration were independent predictors of thoracic injury due to chest compression.[26] In our study, age remained a significant risk factor for severe intrathoracic hemorrhage requiring TAE even after multivariate adjustment. However, low flow time was not a significant risk factor. This could be due to differences in the patient population and the possibility that patients receiving ECPR generally have longer chest compression times with less variation, making it difficult to detect differences based on compression time and differences in outcome definitions. This pattern was consistent across both IHCA and OHCA subgroups, where we observed no significant differences in low flow time or the incidence of severe intrathoracic hemorrhage requiring TAE. Given the limited sample size in each subgroup, these findings should be interpreted cautiously and warrant further investigation in larger studies. Moreover, research on the relationship between thoracic cage shape and CPR-related intrathoracic injuries is lacking. Beesems et al.,[27] in their study using LUCAS 2, reported considerable variation in the force required to achieve adequate compression depth, suggesting that the thoracic cage structure may influence the mechanics of CPR. A Spanish report showed that the risk of severe thoracic complications due to chest compressions increases with a wider transverse diameter of the thorax.[28] Age and obesity can cause rib horizontalization, leading to changes in the thoracic cage shape with an increased thoracic transverse diameter.[29,30] This alteration in mechanical properties may increase the force required to perform effective CPR.[28]

Our results provide several clinical implications regarding the use of mechanical CPR devices during ECPR. Although mechanical CPR devices provide consistent compression and may be beneficial in certain circumstances, clinicians should consider their use carefully, especially in patients with risk factors such as advanced age or large thoracic transverse diameter. Rather than adhering to a "one-size-fits-all" method, the depth and force of compressions may need to be adjusted based on the individual patient's characteristics, particularly the thoracic cage dimensions. Enhanced monitoring is essential when mechanical CPR devices are used during ECPR. This should include frequent imaging to detect the early signs of intrathoracic hemorrhage, especially in high-risk patients. It is also crucial to raise awareness among all team members involved in ECPR regarding the increased risk of potential intrathoracic hemorrhage associated with mechanical CPR. Implementing these strategies may help mitigate the risks associated with mechanical CPR, while leveraging its benefits under appropriate circumstances.

Limitations

Our study had several limitations. First, this was a single-center retrospective cohort study, which inherently limits the generalizability of our findings. The retrospective nature of the study may have introduced a selection bias, particularly in the choice of CPR method, which was not randomized. Second, the sample size of 91 patients, while substantial for an ECPR study, may have limited our ability to detect minor differences between the groups or perform more extensive subgroup analyses. This was reflected in the wide confidence intervals for some of our estimates, particularly in the multivariate analysis. Third, while the quality of manual CPR or the characteristics of different mechanical CPR device types may have influenced the results, manual CPR was performed by trained emergency staff or paramedics and LUCAS 3 was used in most cases. Finally, our study was conducted at a single institution in Japan and the results may not be directly applicable to healthcare systems with different ECPR protocols, resources, and patient populations.

Despite these limitations, our study provided valuable insights into the potential risks associated with mechanical CPR during ECPR. We attempted to address some of these limitations using robust statistical methods, including multivariate analysis and IPTW. Future prospective multicenter studies with larger sample sizes are required to confirm and extend our results.

Conclusion

In conclusion, our study demonstrated that the use of mechanical CPR devices during ECPR is associated with an increased risk of severe intrathoracic hemorrhage requiring TAE compared with manual CPR. This risk is particularly pronounced in older patients and in those with larger thoracic transverse diameters. Despite these complications, we observed no significant difference in the 180-day survival rates between the mechanical and manual CPR groups. These findings highlight the need for a more nuanced approach to mechanical CPR during ECPR, considering individual patient characteristics, particularly age and thoracic dimensions. Enhanced monitoring for early detection of intrathoracic hemorrhage is crucial when these devices are employed. Although mechanical CPR devices offer benefits in certain ECPR scenarios, clinicians must carefully weigh them against the increased risk of complications.

Declaration of AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used Claude (Claude 3.5 Sonnet, developed by Anthropic) in order to check the English grammar and spelling. After using this too, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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CRediT authorship contribution statement

Yoshihisa Matsushima: Writing – original draft, Visualization, Investigation, Formal analysis, Data curation, Conceptualization. **Tatsuhiro Shibata:** Writing – original draft, Visualization, Project administration, Methodology, Formal analysis, Data curation, Conceptualization. **Kodai Shibao:** Writing – review & editing, Visualization, Methodology, Conceptualization. **Rei Yamakawa:** Investigation. **Miyu Hayashida:** Investigation. **Toshiyuki Yanai:** Investigation. **Takashi Ishimatsu:** Investigation. **Takehiro Homma:** Investigation, Conceptualization. **Shoichiro Nohara:** Writing – review & editing, Investigation, Conceptualization. **Maki Otsuka:** Writing – review & editing, Investigation, Conceptualization. **Yoshihiro Fukumoto:** Writing – review & editing, Project administration, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary material

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Author details

[a]Division of Cardiovascular Medicine Department of Internal Medicine Kurume University School of Medicine Kurume Japan [b]Division of Cardiac Care Unit Advanced Emergency Medical Service Center Kurume University Hospital Kurume Japan [c]Department of Epidemiology, Johns Hopkins Bloomberg School of Public Health Baltimore MD USA

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