



## Original Article

# Cardiac arrest during hemodialysis: a survey of five Japanese hospitals

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**Aim:** Intraoperative cardiac arrest is a serious complication among patients receiving hemodialysis. However, the frequency and reaction to these events remain unclear. This study aimed to explore the clinical picture of cardiac arrest during hemodialysis.

**Methods:** Ten cardiac arrests that had occurred during 217,984 hemodialysis treatments in five Japanese hospitals, between 2008 and 2017, were reviewed. We investigated the underlying disease, vital signs, emergency responses, and outcomes using patient medical records.

**Results:** The cardiac arrest rate ranged from 1.1 to 7.5 per 100,000 hemodialysis sessions. All included cases of cardiac arrest occurred in a hemodialysis unit and had been witnessed and reported by supervising clinicians. The initial rhythm was ventricular fibrillation/ventricular tachycardia in six patients (60%) and pulseless electrical activity/asystole in four patients (40%). Seven (70%) patients showed a return of spontaneous circulation (ROSC), and two (20%) patients were discharged with a cerebral performance category score of 1. There was a statistically significant difference in the ROSC rate ( $P = 0.048$ ) only in the event of an emergency call. The SpO<sub>2</sub> and respiratory rates had not been recorded in six patients. There was no significant difference in ROSC between initial rhythms of ventricular fibrillation/ventricular tachycardia and pulseless electrical activity/asystole.

**Conclusion:** We evaluated the frequency of cardiac arrest during hemodialysis. Overall assessment including respiratory status is needed at initiation of hemodialysis. In case of a sudden change in a patient's status, high-quality resuscitation treatment that includes an emergency call can improve prognosis.

**Key words:** Cardiac arrest, cardiopulmonary resuscitation, chronic kidney failure, hemodialysis, sudden death

## INTRODUCTION

IN THE 1960S, the “Life or Death Committee,” located in Seattle in the USA, selected end-stage renal disease (ESRD) patients for dialysis.<sup>1</sup> The prevalence of hemodialysis has increased ever since. In 2016, there were 329,609 dialysis cases in Japan.<sup>2</sup> In addition to common

cardiovascular risk factors such as hypercholesterolemia, hypertension, and obesity, a strong association exists between ESRD and acute inflammation, oxidative stress, endothelial dysfunction, insulin resistance, and excess sympathetic tone.<sup>3,4</sup> Patients with ESRD have a unique pathology of cardiovascular, electrolyte, and fluid abnormalities compared to non-dialysis patients.<sup>5,6</sup>

In Japan, the annual mortality from hemodialysis is 31,000, with an annual mortality rate of 96.4 per 1,000 and a crude death rate of 9.7.<sup>2</sup> This mortality rate is approximately nine times that of the general population.<sup>7</sup> In the USA, the reported mortality rate for patients undergoing hemodialysis is more than twice that of the general population.<sup>8</sup> The major causes of death have been reported to be related to cardiovascular issues (38%) and sudden death

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(24%).<sup>7</sup> Circulatory system dynamics and electrolyte levels could fluctuate during hemodialysis; the likelihood of sudden changes should also be acknowledged. However, few studies have assessed these sudden changes that occur during hemodialysis;<sup>9–11</sup> in addition, these studies have all been undertaken outside Japan.

In this study, we investigated the incidence of cardiac arrest in Japanese patients undergoing regular maintenance hemodialysis and examined the contents and outcomes concerning resuscitation procedures.

## METHODS

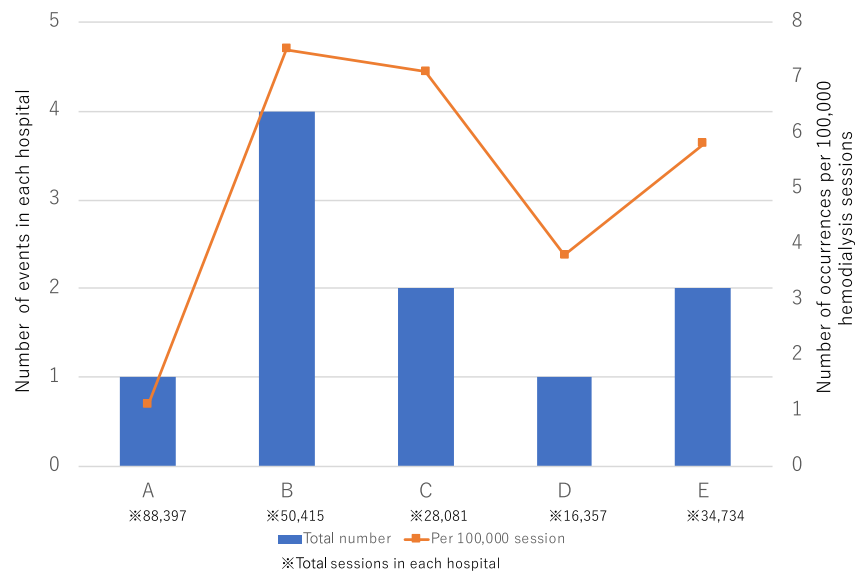
WE RETROSPECTIVELY INVESTIGATED the data of patients who had a cardiac arrest during their hemodialysis sessions in five of our related hospitals, namely, the Kawasaki Municipal Tama Hospital (A, our hospital), St. Marianna University School of Medicine (B, hemodialysis for inpatients only), St. Marianna University School of Medicine, Yokohama City Seibu Hospital (C), Tokyo Bay Urayasu Ichikawa Medical Center (D), and Inagi Municipal Hospital (E). These hospital facilities are certified by the Japanese Society of Dialysis Therapy, and work in cooperation with our hospital; we were able to tally their medical records. We used data extracted during medical record reviews, and the requirement for patient consent was waived due to the retrospective nature of the study. The relevant personnel of the participating hospitals were informed of the study protocol; no objections were raised. The study

protocol was approved by the Bioethics Committee of St. Marianna University School of Medicine (approval no. 3985). The collection periods were as follows: from 2008 to 2017 (hospitals A and B), from 2012 to 2017 (hospital C), from 2013 to 2017 (hospital D), and from 2010 to 2017 (hospital E). Hospitals A, D, and E are secondary emergency hospitals, and hospitals B and C are tertiary emergency hospitals. We obtained the data of all patients with sudden changes reported during hemodialysis sessions from the records, and selected cardiac arrest cases for inclusion in the analysis. Individual demographic data were obtained from patients' general medical records. We examined the patients' records for underlying diseases, vital signs at initiation of hemodialysis, emergency responses according to guidelines<sup>12</sup> for cardiopulmonary resuscitation after a sudden change, and outcomes. Abnormal vital signs included systolic blood pressure <90 mmHg, pulse <40 b.p.m. or >100 b.p.m., respiratory rate >22 breaths/min, SpO<sub>2</sub> <94% or administration of oxygen, and a Glasgow Coma Scale score <15. Responses to sudden changes were evaluated according to the Basic Life Support and Advanced Cardiovascular Life Support guidelines.<sup>12</sup>

Four patients who had a “do not attempt resuscitation” order from the initiation of the study period were excluded.

## Statistical analysis

We used a direct probability test to analyze the relationship between treatment given during a sudden change event and



**Fig. 1.** Total numbers of cardiopulmonary arrest events during hemodialysis in five hospitals in Japan and numbers per 100,000 hemodialysis sessions in each hospital.

the return of spontaneous circulation (ROSC), and between the initial waveform and the ROSC. Fisher's exact test was applied using JMP 13.2 (SAS Institute, Tokyo, Japan). Two-sided *P*-values <0.05 were considered to be statistically significant.

## RESULTS

**D**URING THE STUDY period, 10 patients had experienced cardiac arrest that occurred during 217,984 hemodialysis treatments in five Japanese hospitals. Figure 1 shows the incidence of cardiac arrest during hemodialysis in these five hospitals. Cardiac arrest occurred at a frequency of 1.1–7.5 times per 100,000 hemodialysis sessions.

Table 1 shows the characteristics of the 10 patients (eight men and two women). The most common underlying disease necessitating hemodialysis was diabetes-related nephropathy. The mean duration from introduction of hemodialysis to cardiac arrest was  $60.9 \pm 43.7$  months. Cardiac arrest occurred most frequently on Fridays, followed by Tuesdays, Wednesdays, and Saturdays.

Most patients did not show abnormal vital signs at the start of hemodialysis. Moreover, respiratory rates had not been recorded in six patients (Table 2). The initial waveforms in six and four patients were ventricular fibrillation

(VF)/ventricular tachycardia (VT) and pulseless electrical activity (PEA)/asystole, respectively.

In total, 7 of 10 patients had a ROSC. There was a statistically significant difference in the ROSC rate ( $P = 0.048$ ) only in the event of an emergency call (Table 3). There was no significant difference in the ROSC between the VF/VT and PEA/asystole groups (odds ratio, 0.25; 95% confidence interval, 0.02–3.77;  $P = 0.55$ ); two (20%) patients with ischemic heart disease survived to hospital discharge. The surviving discharged patients had a neurological prognostic Glasgow–Pittsburgh Cerebral Performance Category score (CPC) of 1. The data of the 10 study patients from five hospitals are presented in Table 4. Each of the five hospitals had variable numbers of hemodialysis beds, and had between one and five doctors, and several clinical engineers and nurses.

## DISCUSSION

**D**EATHS DUE TO cardiovascular events are common among patients on hemodialysis. End-stage renal

**Table 1.** Characteristics of patients who underwent cardiac arrest during hemodialysis ( $n = 10$ )

Characteristic	
Age, years	$73.9 \pm 8.9$
Sex, male : female	8:2
Inpatient : outpatient, <i>n</i>	8:2
Medical history	
Diabetes mellitus	6
Hypertension	7
CHD	5
CHF	6
Arrhythmia	3
Stroke	0
PVD	3
Original renal disease	
Diabetes-related nephropathy	5
Chronic glomerulonephritis	1
Nephrosclerosis	0
Others, unknown	4
History of hemodialysis, months	$60.9 \pm 43.7$

CHD, coronary heart disease; CHF, chronic heart failure; PVD, peripheral vascular disease.

**Table 2.** Vital signs at initiation of hemodialysis among patients who underwent cardiac arrest ( $n = 10$ )

	Abnormal	Normal	Not recorded
Bp	1	9	0
HR	4	6	0
BT	1	7	2
SpO2	5	3	2
RR	2	2	6
LOC	4	6	0

BP, blood pressure; BT, body temperature; HR, heart rate; LOC, level of consciousness; RR, respiratory rate; SpO2, peripheral capillary oxygen saturation.

**Table 3.** Factors affecting return of spontaneous circulation (ROSC) in patients who underwent cardiac arrest during hemodialysis ( $n = 10$ )

	ROSC (+)	ROSC (–)	<i>P</i> -value
Number of patients	7	3	
Shock	6	2	1.000
Emergency call	5	0	0.048*
Retransfusion	6	2	1.000
Intubation	4	2	1.000
Drug administration	6	2	1.000

\**P*-value < 0.05.

**Table 4.** Summary of five hospitals (A–E) and 10 patients who underwent cardiac arrest during hemodialysis (HD) (*n* = 10)

Facility	Period	HD sessions	Patient / staff	Patient no.	Age, years	Sex	Disease due to admission	Day of week	Initial waveform	ROSC	Survived to discharge
A	2008–2017	88,397	24/DR.1, CE4, NS8	1	65	M	Outpatient	Sat	VFVT	○	○
B	2008–2017	50,415	16/DR3, CE5, NS7	2	83	F	RCC pain control	Fri	VFVT	×	×
				3	64	M	Colovesical fistula	Mon	Asystole	○	×
				4	85	F	Shunt trouble	Wed	PEA	○	×
				5	76	M	Cervical abscess	Fri	PEA	○	×
C	2012–2017	28,081	14/DR5, CE2, NS8	6	85	M	SAH	Wed	PEA	○	×
				7	72	M	CABG	Fri	VFVT	○	○
D	2013–2017	16,357	13/DR3, CE2, NS5	8	58	M	ACS	Tue	VFVT	○	○
E	2010–2017	34,734	10/DR1, CE2, NS4	9	72	M	Outpatient	Tue	VFVT	×	×
				10	79	M	Heart failure	Sat	VFVT	×	×

○, yes; ×, no; ACS, acute coronary syndrome; CABG, coronary artery bypass grafting; CE, clinical engineer; DR, doctor; F, female; M, male; NS, nurse; PEA, pulseless electrical activity; RCC, renal cell carcinoma; ROSC, return of spontaneous circulation; SAH, subarachnoid hemorrhage; VF, ventricular fibrillation; VT, ventricular tachycardia.

disease dramatically increases the risk of cardiovascular or sudden death, and is associated with 70% of cardiovascular deaths and 27% of all deaths in patients undergoing hemodialysis.<sup>13</sup> In the USA, 40% of cause-specific mortality in patients on hemodialysis have been attributed to arrhythmia and cardiac arrest. In addition to ischemic heart disease, diminished tolerance to myocardial ischemia, rapid changes in electrolyte levels, and derangements in autonomic function could all contribute to sudden cardiac death.<sup>6,8,14</sup> Overall, heart failure is the largest cause of death in patients undergoing hemodialysis in Japan, causing between 26% and 27% of all deaths in this cohort in recent years.<sup>2</sup>

Other than conventional risk factors, additional multifaceted factors are associated with an increased risk of cardiovascular complications in these cases; these have not been fully elucidated to date.<sup>6</sup> Several related mediators cause functional and structural changes; they might exacerbate inflammation, enhance sympathetic nervous activity, increase oxidative stress, cause disturbances in mineral balance, and impair vascular endothelial function. Anemia, high blood pressure, and excess fluid accumulation are prevalent; changes including myocardial fibrosis, blood vessel calcification, and thickening of the tunica intima have been reported to cause heart failure.<sup>3–6</sup>

In this study, we examined cases where cardiac arrest occurred during hemodialysis in three secondary emergency medical institutions, including our hospital, and in two tertiary emergency medical institutions. The number of cases per 100,000 hemodialysis sessions was high in the tertiary emergency hospitals; this was considered related to the severity of the cases. The incidence of cardiopulmonary arrest in previous reports has varied from 7 to 80,<sup>9–11</sup> and our report also found differences between hemodialysis facilities (Table 5). The average age of patients on hemodialysis was high, and they were likely to have other comorbidities; however, the occurrence of cardiopulmonary arrest was low. It appears that the safety of hemodialysis has improved over time. According to a previous report, many cardiac arrests have occurred on either a Monday or a Tuesday;<sup>11</sup> however, in our investigation, the days of occurrence differed from those of previous reports. In one report, the authors hypothesized that the 3-day hemodialysis-free interval resulted in greater fluid overload and fluctuations in electrolytes and toxins<sup>11</sup>. Although the hemodialysis-free interval was not examined in our study, we did not observe any relationship between the day and the cardiovascular event.

Respiratory status is considered an essential, basic vital sign. We noted that few patients had abnormal blood pressure readings or pulse rates at initiation of hemodialysis; however, five patients showed a reduced SpO<sub>2</sub> level, or

**Table 5.** Review of published reports of cardiopulmonary arrest (CPA) cases during hemodialysis (HD)

	Lai <i>et al.</i> <sup>9</sup>	Karnik <i>et al.</i> <sup>10</sup>	Lafrance <i>et al.</i> <sup>11</sup>	Our study
Age, years; mean	66.8 ± 16.8	66.3 ± 12.9	64.5 ± 14.2	72.9 ± 12.7
HD sessions, <i>n</i>	29,699	57,44,708	3,07,553	2,17,984
CPA, <i>n</i>	24	400	24	10
Per 100,000 HD sessions, <i>n</i>	80	7	7.8	4.6

needed oxygen. The SpO<sub>2</sub> and respiratory rates of six patients had not been documented.

Chest compressions and assisted ventilation were provided as treatment for the sudden change in all cases. An emergency call was required for only five patients as medical staff were present at the scene and could assemble immediately in the hemodialysis unit.

Comparison of the ROSC and non-ROSC groups showed a significant difference in the event of the emergency call; this indicated the importance of emergency calls in resuscitation. In this study, patients with an initial waveform of VF/VT did not achieve ROSC more frequently than those with PEA/asystole; this was inconsistent with previous reports concerning in-hospital cardiac arrest.<sup>15,16</sup>

Two (20%) patients survived to hospital discharge, and both had a favorable neurological CPC prognostic score of 1. Girotra *et al.* reported that the survival rate of hospitalized patients with cardiac arrest, including those in the general ward and the intensive care unit, was 22%. Moreover, they reported a neurological prognosis (CPC > 1) in 28% of patients; this was equivalent to our study findings.<sup>17</sup>

Patients undergoing hemodialysis have higher risks of complications than those not undergoing the procedure; particular care should be taken due to the possibility of sudden changes and sudden cardiac arrest. During hemodialysis, medical personnel should observe patients carefully and implement an immediate chain of survival. The first chain should involve a suitable monitoring system for preventing in-hospital cardiac arrest, and should include evaluation and observation of the medical condition before and during hemodialysis.<sup>18</sup> Once a cardiac arrest occurs during hemodialysis, doctors, nurses, clinical engineers, and those present in the field should work together to request an in-hospital emergency call, which should be the second chain. Implementation of prompt and high-quality on-site resuscitation is critical for improving outcomes.

## Limitations

This study had certain limitations. We only assessed 10 patients; the sample size was considerably inadequate for

effectively examining the occurrence of cardiac arrest and the effects of resuscitation. We reviewed patient medical records from multiple hospitals, with different types and formats of the medical records; this limited data consistency.

## CONCLUSION

**I**N THIS STUDY, we observed cardiac arrest trends during hemodialysis. Most patients on hemodialysis are at high risk; therefore, an appropriate assessment including the respiratory status is required at initiation of hemodialysis. In cases of sudden change to a patient's status, high-quality resuscitation treatment that includes an emergency medical call can improve prognosis.

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## DISCLOSURE

Approval of the research protocol: This study was approved by the Bioethics Committee of St. Marianna University School of Medicine (approval no. 3985).

Informed consent: N/A.

Registry and registration no. of the study/trial: N/A.

Animal studies: N/A.

Conflict of interest: None.

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