Research Article

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Influence of Pre-Electrical Cardioversion Potassium Test Timing on Ventricular Arrhythmic Complications and Success Rates

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Abstract

Objectives: Elective electrical cardioversion (ECV) is frequently used for supraventricular tachycardia therapy. However, the success rate of this approach varies, and ventricular arrhythmias may develop as a consequence. We aimed to determine whether the timing of pre-ECV potassium serum testing affects patient outcomes.

Materials and Methods: This retrospective cohort study analyzed 65 patients who underwent elective ECV in 2023. Patients were divided into two groups (short-interval vs long-interval) based on the median time (in days) between the potassium test and ECV. The primary outcome measure was the incidence of ventricular arrhythmias, whereas the secondary outcome measure was immediate restoration of sinus rhythm.

Results: The median time between the potassium test and ECV was 57 (interquartile range 135) days. No ventricular arrhythmias were observed. There was no statistically significant difference in success rates between the two groups (84.8% versus 84.4%; p=0.958; χ^2 test). Predetermined risk factors for potassium disturbances did not influence success rates.

Conclusion: Our study suggests that the timing of potassium serum testing does not influence the occurrence of ventricular arrhythmias following elective ECV. In addition, the timing of serum potassium testing did not influence the success rate. Therefore, potassium testing shortly before cardioversion may not be necessary.

Keywords: Electrical cardioversion, potassium, ventricular arrhythmias, serum testing

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Introduction

Electrical cardioversion (ECV) is a medical procedure that was first performed in the 1950s[1]. To this day, ECV remains a fundamental intervention in the management of various cardiac arrhythmias. The objective of ECV is to administer an external electric shock that depolarizes all excitable cardiac cells, rendering them refractory, interrupting the re-entry circuit responsible for the arrhythmia, and allowing the sinoatrial node to restore sinus rhythm. In the Canisius-Wilhelmina Ziekenhuis (CWZ) alone, approximately 400 elective ECVs are conducted annually. Immediate success rates are typically quite high, varying from 69.4% to 94.2%[1,2]. Although uncommon, ventricular arrhythmias can occur as a direct complication of ECV and pose significant risks to patients.

Potassium is an essential electrolyte that is mostly found intracellularly in cardiac cells and plays a major role in cardiac electrophysiology. It participates in maintaining the resting membrane potential and repolarization of the cell membrane after each action potential. When extracellular potassium concentration is high, the resting membrane potential is depolarized, leading to spontaneous depolarization. When extracellular potassium concentration is low, the cell membrane becomes hyperpolarized and the conduction velocity and rate of diastolic depolarization[3]. In this way, disturbances in extracellular potassium can cause cardiac arrhythmias. Hence, potassium levels are strictly regulated. However, certain conditions and medications can pose a threat to the potassium balance. For example, commonly prescribed antihypertensive drugs like angiotensin-converting enzyme (ACE) inhibitors and angiotensin receptor blockers (ARB) inhibit the renin-angiotensin system, causing a decrease in aldosterone production. This condition causes less efficient urinary potassium excretion and can potentially lead to hyperkalemia. Moreover, patients with impaired renal function may also have problems excreting potassium, potentially causing hyperkalemia. A study found that among participants in the Dutch general population aged between 65 and 74 years, the prevalence of hypokalemia was 2.7%, whereas the prevalence of hyperkalemia was 0.2%[4].

Given the importance of potassium in cardiac electrophysiology, serum potassium levels may also influence the onset of arrhythmias following ECV. Moreover, one study found that intravenous injection of potassium and magnesium before the start of ECV might positively impact the procedure's success rate[5]. However, current guidelines and the CWZ protocol do not provide any recommendations regarding the monitoring or administration of potassium prior to ECV[6]. Nevertheless, most patients in the CWZ undergoing elective ECV have a recorded serum potassium level, although the timing of these measurements can vary, with some having a recent measurement and others having a less recent. This study aimed to gain more insight into how the timing of serum potassium testing affects arrhythmic complications and the success rate of elective ECV.

Materials and Methods

Study Design and Participants

Due to the retrospective nature of the study, ethics committee/IRB approval was waived. However, informed consent from the patient was received according to the ethical principles of the Declaration of Helsinki. The study was assessed by the Local Ethics Committee and registered in the context of transparency. A list of 108 patients who underwent ECV between February and August 2023 was acquired. Eligible participants were >18 years of age, had a documented serum potassium level, and had undergone ECV. The exclusion criteria were use of cardiac implantable electronic devices and active ventricular arrhythmias.

The median time (in days) from the potassium test to ECV was determined to divide patients into two groups. The group with a time interval less than the median was referred to as the "short interval group", while the group with a time interval exceeding the median was referred to as the "long interval group".

Cardioversion Protocol

In accordance with the European Society of Cardiology guidelines, all patients who had been experiencing atrial fibrillation (AF) for longer than 48 hours underwent pretreatment with oral anticoagulation therapy for a minimum of 3 weeks. The attending anesthesiologist sedated patients by intravenous Propofol administration. Paddles were positioned in an anterior-apical position, and ECV was performed using biphasic shock. The specific starting volume of joules delivered was determined by a nurse specialist. If necessary, additional shocks were administered following the step-up protocol, with a maximum of three shocks administered per session. Patients were monitored using telemetry for 1 hour before discharge.

Data Collection and Variable Selection

A database was constructed using data extracted from the electronic health record (EHR). Various demographic and clinical characteristics were assessed to compare baseline characteristics between the two groups. For comorbidities, a history of heart failure, diabetes, or coronary artery disease was considered. Specifically, diabetes type II was chosen because multiple studies have shown that this disease is an independent factor that negatively influences the immediate success rate of ECV[7,8]. The presence of comorbidities was determined based on the clinical notes in the patient EHR. Coronary artery disease was defined as typical angina pectoris, acute coronary syndrome, significant stenosis on angiogram, and previous coronary revascularization therapy. Heart failure comprised both preserved ejection fraction and reduced ejection fraction. Impaired renal function was documented because it is known to cause hyperkalemia. This impairment was defined as an estimated glomerular filtration rate <60 mL/kg/1.73m² measured with the chronic kidney disease epidemiology collaboration method.

Furthermore, we documented the use of anti-arrhythmic drugs (AADs). Type III AADs improve the success rate of acute restoration of sinus rhythm[9], thereby making them a significant baseline characteristic. We also documented the use of ACE inhibitors, ARBs, and diuretics because these medications are known to cause disturbances in serum potassium levels and thus may influence serum potassium levels during ECV.

Outcome Measures

The primary outcome measure was the onset of a new arrhythmia as a direct complication of the ECV, which was defined as ventricular tachycardia (VT), ventricular fibrillation (VF), or Torsade de Pointes.

The secondary outcome measure was the ECV success rate. Successful cardioversion was defined as a restored sinus rhythm immediately after cardioversion. Both outcomes were measured by 12-lead ECG immediately after cardioversion and were examined by an attending nurse specialist.

Statistical Analysis

Categorical variables are expressed as counts and percentages, whereas continuous variables are expressed as means and standard deviations. To examine differences in characteristics between the short and long interval groups, the chi-square test was used for categorical values. However, in cases in which one or more cells had expected counts of less than five, we opted for Fisher's exact test to ensure the reliability of our test. A Shapiro-Wilk test was performed to determine whether continuous variables followed a normal distribution. For normally distributed continuous data, an independent sample t-test was conducted, and for non-normally distributed data a Mann-Whitney U test was performed. P-value 0.05 was considered statistically significant. All analyses were performed using IBM SPSS version 24.

Results

Participants

After selecting patients and reviewing the EHRs, a total of 65 patients were included. Figure 1 presents the

details of participant enrollment. The median time from potassium serum test to ECV was 57 (interquartile range 135), which split the patients into two groups: the short-interval group and long-interval group.

Figure 2 presents the spread of the time interval in days between the potassium test and ECV, as depicted in the boxplots. Table 1 lists the baseline characteristics. There were no statistically significant differences in demographic and clinical baseline characteristics observed. The majority of patients were male and were treated with class II AADs. In the long-interval group, one patient experienced mild hyperkalemia and two patients experienced mild hypokalemia. In the short-interval group, no potassium disturbances were observed.

Ventricular Arrhythmia Complications

In this study, the primary outcome of interest was the occurrence of VTs and conduction disorders directly following ECV. Our analysis revealed that none of the participants experienced VF, VT, or Torsade de Pointes.

Immediate Success of ECV

In our cohort, restoration of sinus rhythm immediately after ECV was achieved in 55 (84.6%) patients. In the short-interval group, ECV was successful in 28 cases compared with 27 cases in the long-interval group (84.8% versus 84.4%; p=0.958). Patients with decreased renal function did not exhibit significantly different success rates following ECV compared with those with normal renal function (83.3% versus 84.9%; p=0.892). In total, 29 patients (44.6%) were using either ACE inhibitors or ARBs. Among these patients, the success rate was 89.7%, whereas it was 80.6% for those not using these medications; this was not statistically different (p=0.312). When comparing success rates between patients who were using loop or thiazide diuretics and those who were not, no statistically significant difference was observed (81.8% versus 85.2%; p=0.778).

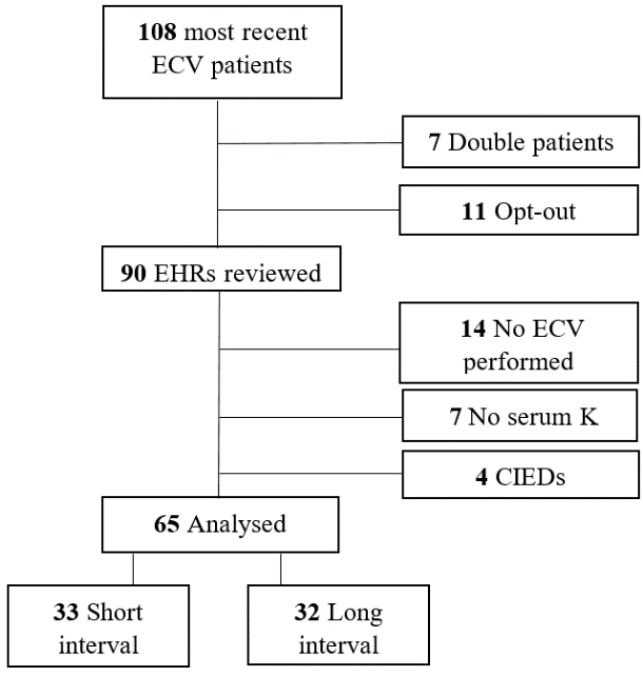

Figure 1. Enrolment
ECV: Electrical cardioversion, EHR: Electronic health record, K: potassium, CIED: Cardiac implantable electronic device

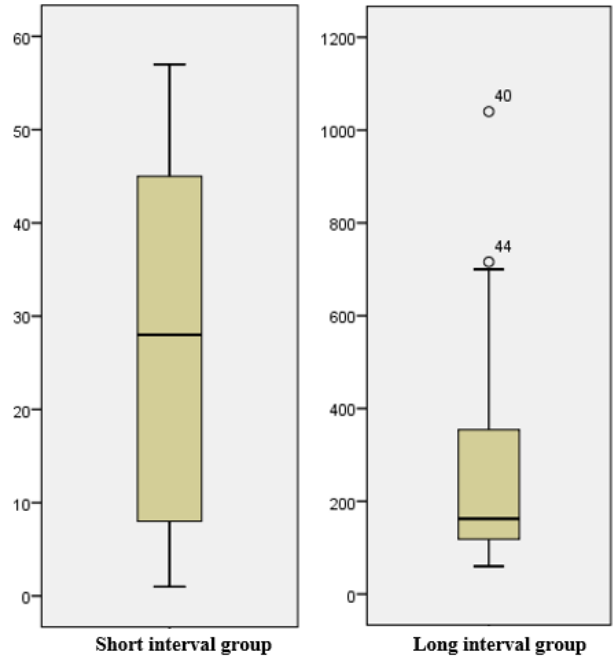

Figure 2. Boxplot of time interval (days) from potassium serum test to ECV
ECV: Electrical cardioversion

Table 1. Demographic and clinical characteristics

Characteristic	Short interval (n=33)	Long interval (n=32)	p-value
Interval between the K test and ECV (days)	28.00 (19.628)	162.50 (223.074)	0.000
Serum potassium (mmol/L)	4.245 (0.3563)	4.194 (0.3501)	0.557
Male sex	20 (60.6%)	26 (81.3%)	0.067
Age (years)	66.88 (9.496)	65.73 (9.478)	0.636
Comorbidities			
Coronary artery disease	5 (15.2%)	7 (21.9%)	0.485
Diabetes mellitus	4 (12.1%)	2 (6.3%)	0.672
Heart failure	10 (30.3)	4 (12.5%)	0.081
Decreased renal function (<60 mL/min/1.73 m²)	7 (21.2%)	7 (15.6%)	0.562
Antiarrhythmic drugs			
Class I	4 (12.1%)	4 (12.5%)	1.000
Class II	31 (93.9%)	29 (90.6%)	0.672
Class III	1 (3.0%)	1 (3.1%)	1.000
Class IV	3 (9.1%)	2 (6.3%)	1.000
Antihypertensive drugs			
ACE-inhibitor	7 (21.2%)	6 (18.8%)	0.804
ARB	11 (33.3%)	5 (15.6%)	0.098
Diuretics			
Potassium-sparing	1 (3.0%)	1 (3.1%)	1.000
Loop or thiazide	8 (24.2%)	3 (9.4%)	0.110

Continuous variables are presented as means and standard deviations. Categorical variables are presented as counts and percentages. P-values were calculated using the chi-squared test, Fisher's exact test, Mann-Whitney U test, or independent samples t-test. Antiarrhythmic drug classes are based on the Vaughan-Williams classification system
ECV: Elective electrical cardioversion, K: Potassium, ACE: Angiotensin-converting enzyme, ARB: Angiotensin receptor blocker

Discussion

In this study, patients who had undergone potassium testing in the past did not exhibit a different risk of developing ventricular arrhythmias compared with those who had the test closer to the ECV. Second, the timing of potassium testing did not influence the success rates of the two groups.

No ventricular arrhythmias as complications following ECV were observed. This finding, which indicated the rarity of ventricular arrhythmic complications, was consistent with that presented in previously performed studies[10,11]. In a large retrospective multicenter study performed by Grönberg et al.[2] 6906 ECVs for acute AF were evaluated for immediate arrhythmic complications. No ventricular arrhythmias requiring intervention were detected, and the authors concluded that arrhythmic complications following ECV are essentially bradyarrhythmia[12]. However, Gallagher et al.[10] studied 2522 ECVs and found 5 cases of VF and 1 case of VT. Of particular interest is that the authors stated that probably all 5 cases of VF were caused by the delivery of an unsynchronized shock. Consequently, these two studies indicate that ventricular arrhythmias as a result of ECV are very rare and are most likely caused by the delivery of unsynchronized shocks.

Regarding the secondary outcomes, no differences in success rates were observed. One limitation of this outcome is that because of the retrospective nature of this study, important predictive factors for success rates, such as thoracic impedance and left atrial size[13], could not be taken into account, as these factors are often not

documented in the EHR. Kyo et al.[13] conducted a study examining success rates after 5 min of ECV in patients with new-onset AF in the intensive care unit. They found that a serum potassium level >3.8 mmol/L at the time of ECV was associated with successful ECV (odds ratio 3.13 95% confidence interval, 1.07-9.11; p=0.04)[14]. Moreover, another study demonstrated that patients who were administered an intravenous potassium and magnesium injection prior to ECV achieved successful restoration of SR significantly more frequently[6]. These findings suggest a positive correlation between higher serum potassium levels and ECV success rates. In our study, however, we did not determine the serum potassium level at the time of ECV.

The primary notion underlying this study was that patients who underwent serum potassium testing more recently would provide physicians with an opportunity to restore potassium imbalances prior to ECV, thereby potentially improving patient outcomes. In our study, however, only three patients experienced mild potassium disturbance, and all three patients belonged to the long-interval group. This outcome implies that our hypothesis may not have been fully tested because no potassium disturbances were noted or corrected in the short-interval group.

Although we did not know serum potassium levels at the time of ECV were unknown, we did analyze specific risk factors, including impaired renal function, the use of diuretics, ARBs, and ACE inhibitors, which are known to contribute to potassium disturbances. However, when comparing patients with these risk factors with those without, we did not observe any statistically significant differences in success rates. Therefore, in our study population, the risk factors for potassium disturbance did not translate into varying ECV success rates.

Study Limitations

Furthermore, this study has several limitations. First, to divide patients into two groups, we used the median time (in days) from potassium serum test to ECV. The designation of "short interval" patients was based on this median. In a different hospital population, the median could vary, potentially leading to different results. Moreover, the "short interval" group still had a large range of approximately 2 months, during which potassium disturbances could still have occurred after the potassium serum test. This study was also limited by its small, single-center design. We exclusively enrolled outpatients undergoing elective ECV. Hospitalized patients experience potassium disturbances more frequently and may have a higher risk of adverse outcomes[15].

In the light of the growing demand for healthcare services in the Netherlands, efficient and evidence-based healthcare practices are crucial. It is crucial that tests are conducted only when valuable information is provided.

Conclusion

In this study, we investigated the timing of potassium serum testing before ECV testing in relation to ventricular arrhythmic complications and success rates. Our findings suggest that, for patients undergoing elective ECV, routine potassium serum testing shortly before ECV has no compelling argument in terms of ventricular arrhythmic complications and success rates. Given this study's limitations, especially its small sample size, further larger-scale research is needed to validate our findings.

Ethics

Ethics Committee Approval: Due to the retrospective nature of the study, ethics committee/IRB approval was waived. However, informed consent from the patient was received according to the ethical principles of the Declaration of Helsinki. The study was assessed by the Local Ethics Committee and registered in the context of transparency.

Informed Consent: Informed consent was obtained from all patients.

Authorship Contributions

Surgical and Medical Practices: Elders J, Concept: Elders J, Design: Elders J, Broekhoven V, Data Collection

and/or Processing: Broekhoven V, Analysis and/or Interpretation: Elders J, Broekhoven V, Remmen J, Cramer M-J, Literature Search: Elders J, Broekhoven V, Writing: Elders J, Broekhoven V.

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