Jurnal Farmasi dan Ilmu Kefarmasian Indonesia
Pharmacy and Pharmaceutical Sciences Journal
Published by Faculty of Pharmacy Universitas Airlangga
OPEN ACCESS
E-ISSN 2580-8303
P-ISSN 2406-9388

Jurnal Farmasi dan Ilmu Kefarmasian Indonesia Vol. 12 No. 1 April 2025, 37-49
DOI: 10.20473/jfiki.v12i12025.37-49
Available online at https://e-journal.unair.ac.id/JFIKI/

Potassium Profile in Heart Failure Patients Before and After Hospitalization at Prof. Dr. I.G.N.G. Ngoerah Hospital

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Submitted: 18 July 2024
Revised: 3 March 2025
Accepted: 20 March 2025

Abstract

Background*: Hypokalemia in patients with heart failure is increasing, with an increasing incidence of 6.8% in Asia and 19.7% in Indonesia; globally, 63 million people suffer from heart failure. Hypokalemia is defined as a serum potassium level below 3.5 mEq/L [mmol/L], which can lead to decreased heart function, muscle weakness, arrhythmias and cardiac arrest. The use of diuretic drugs such as furosemide in heart failure patients may be a risk factor for hypokalemia. Objective: This study aims to determine the difference in potassium levels before and after furosemide administration as well as the possibility of hypokalemia due to furosemide administration in inpatients diagnosed with heart failure at Prof. Dr. I.G.N.G. Ngoerah Hospital. Methods: This is a cross-sectional observational study with retrospective medical record collection. The minimum sample size was calculated using Lemeshow's Formula of One Proportion Estimation Method with Absolute Precision Proportion, data normality test with Kolmogorov-Smirnov ($p>0.05$) and parametric test with paired t-test ($p<0.05$). This study included 101 patients that met the inclusion criteria with 11 patients having more than one inpatient visit, so a total 114 'patients' medical records were obtained. Results: Potassium levels before and after hospitalization showed a significant difference ($p<0.05$). A total of 84 'patients' data showed a decrease in potassium levels, with 49 of them showing a reduction in >15% and 35 showing a decrease of ≤15%. Conclusion: Prevalence of hypokalemia in patients with a diagnosis of heart failure and furosemide therapy at Prof. Dr. I.G.N.G. Ngoerah Hospital during January 2022-December 2023 after hospitalization was 29%.*

Keywords*: furosemide, heart failure, hypokalemia, potassium*

How to cite this article:
Aryani, K. I., Swastiartha, N. P. I., Putri, N. K. A. K. S., Pratiwi, N. K. M. A., Wahyudi, M. S. & Noviyanti, R. (2025). Potassium in Heart Failure Patients Before and After Hospitalization at Prof. Dr. I.G.N.G Ngoerah Hospital. *Jurnal Farmasi dan Ilmu Kefarmasian Indonesia*, 12(1), 37-49. http://doi.org/10.20473/jfiki.v12i12025.37-49

P-ISSN: 2406-9388
E-ISSN: 2580-8303

INTRODUCTION

Heart failure is caused by abnormalities in the function and structure of the heart that can interfere with the ventricles filling and pumping blood to the heart (Heidenreich et al., 2022). According to the European Society of Cardiology (ESC), by 2022, an estimated 63 million people worldwide will suffer from heart failure (Rosano et al., 2022). Indonesia has the second-highest number of heart failure patients in Asia (Savarese et al., 2022). According to Riset Kesehatan Dasar (Riskesdas), in 2018, 1.5% or nearly 4 million Indonesians suffered from heart failure. Bali is in 21st place with 1.1% of heart failure patients (Kemenkes RI, 2018). Heart disease is the second-highest cause of death after stroke in Indonesia (Donsu et al., 2020). Death in heart failure patients can be caused by several conditions, such as shortness of breath, fatigue and fluid retention (DiPiro et al., 2021). Fluid retention is the impact of the heart's compensatory response in maintaining heart function and can cause edema, difficulty breathing, and an increase in the amount of phlegm (DiPiro et al., 2021; PERKI, 2020). One way to treat fluid retention is to administer diuretic drugs such as furosemide, which prevents the reabsorption of potassium, sodium, and chloride in the henle loop thereby increasing the excretion of water and salt through the urine. However, furosemide administration in heart failure patients is associated with a 30% incidence of hypokalemia (Aimbudlop & Saengpanit, 2023).

Hypokalemia is a clinical condition when the concentration of potassium in the blood serum is less than 3.5 mEq/L (mmol/L), which can cause decreased heart function, arrhythmias, and cardiac arrest (DiPiro et al., 2021). This condition can be caused by comorbidities in heart failure patients such as kidney failure (Sarnowski et al., 2022; Thomsen et al., 2018), diabetes (Thomsen et al., 2018), and gastric bleeding (Rizos et al., 2017), as well as the use of drugs such as Angiotensin Converting Enzyme inhibitors (ACEi), Angiotensin Receptor Blocker (ARB), beta-blockers, spironolactone, and diuretics called furosemide (Chang et al., 2016; Rawal et al., 2020). One way to prevent hypokalemia in heart failure patients is by monitoring potassium levels before and after administration of diuretics such as furosemide and paying attention to the correct dosage. Therefore, this study was conducted to analyze potassium levels before and after hospitalization in heart failure patients receiving furosemide therapy and the possibility of hypokalemia in heart failure patients due to furosemide administration at Prof. Dr I.G.N.G. Ngoerah Hospital.

MATERIALS AND METHODS

Observational research with a cross-sectional design and retrospective collection of medical record data has been carried out and ethical exemption obtained from the Ethics Commission of the Faculty of Medicine, Udayana University No.1300/UN14.2.2.VII.14/LT/2024 with protocol number 2024/01/1/0602 and a research permit from Prof. Dr. I.G.N.G. Ngoerah Hospital with number DP.04.03/D.XVII.2.2.2/27373/2024. Sample data were collected from medical records of heart failure patients at Prof. Dr. I.G.N.G. Ngoerah Hospital who met the exclusion and inclusion criteria while hospitalized in the period January 2022-December 2023 using a purposive sampling method.

Materials

The tools used in this research are data collection forms, Statistical Package for the Social Sciences (SPSS) Version 29, and Microsoft Office applications for data processing. The materials used in this research comprise medical record data of patients diagnosed with heart failure at Prof. Dr. I.G.N.G. Ngoerah Hospital during the period January 2022-December 2023. The medical record data used included patient identity, patient diagnosis, hospital admission and discharge dates, patient final status (death or recovery), disease history, 'patients' laboratory data such as laboratory data such as pre- and post-hospitalization potassium data, sodium, creatinine, BUN, and eGFR; body mass index (BMI), and 'patients' medication history such as patients' daily medicine prescribed data, past medical history, and drug usage history.

Population

The population in this research included all patients who had been diagnosed with heart failure at Prof. Dr. I.G.N.G. Ngoerah Hospital during the period January 2022-December 2023. The inclusion criteria included patients with a diagnosis of heart failure who received furosemide therapy as a diuretic during their hospitalization at Prof. Dr. I.G.N.G. Ngoerah Hospital and had complete potassium data in their medical records during the period January 2022-December 2023. The exclusion criteria included patients with untraceable and unreadable medical records. The minimum sample size was calculated using the Lemeshow Formula One Proportion Estimation Method with Absolute Precision.

$$n = \frac{Z^2{}_{1-\alpha/2} + P(1-P)}{d^2}$$

The calculations were made with a 95% confidence level (1-α value) and an absolute precision of 0.09. The anticipated population proportion (P1) value refers to

P-ISSN: 2406-9388
E-ISSN: 2580-8303

research by Aimbudlop and Saengpanit (2023), which stated that the prevalence of hypokalemia patients is 0.3, so the minimum sample size obtained is 100 samples.

Data analysis

Data on patient characteristics, potassium levels before and after hospitalization, and data on patients with comorbid kidney failure, including potassium levels in patients diagnosed with heart failure and receiving furosemide at Prof. Dr I.G.N.G. Ngoerah Hospital, during the period January 2022 - December 2023 have been collected for descriptive and statistical analysis. The normality test was carried out using the Kolmogorov-Smirnov method ($p>0.05$), and the parametric test using the paired t-test method ($p<0.05$) was applied only to potassium level data before and after hospitalization. Meanwhile, descriptive analysis was applied to patient characteristics data and potassium level data in patients with comorbid kidney failure. The SPSS Version 29 application was used for statistical tests.

RESULTS AND DISCUSSION

Figure 1. Flowchart of Hospitalized Heart Failure Patients Receiving Furosemide with Available Potassium Data Before and After Hospitalization at Prof. Dr. I.G.N.G. Ngoerah Hospital from January 2022 to December 2023

Characteristics of patients

The data obtained included 101 patient medical records that met the inclusion criteria, with 11 patients having more than one inpatient visit so a total 114 'patient's medical records were obtained. Characteristics of patients are shown in Table 1.

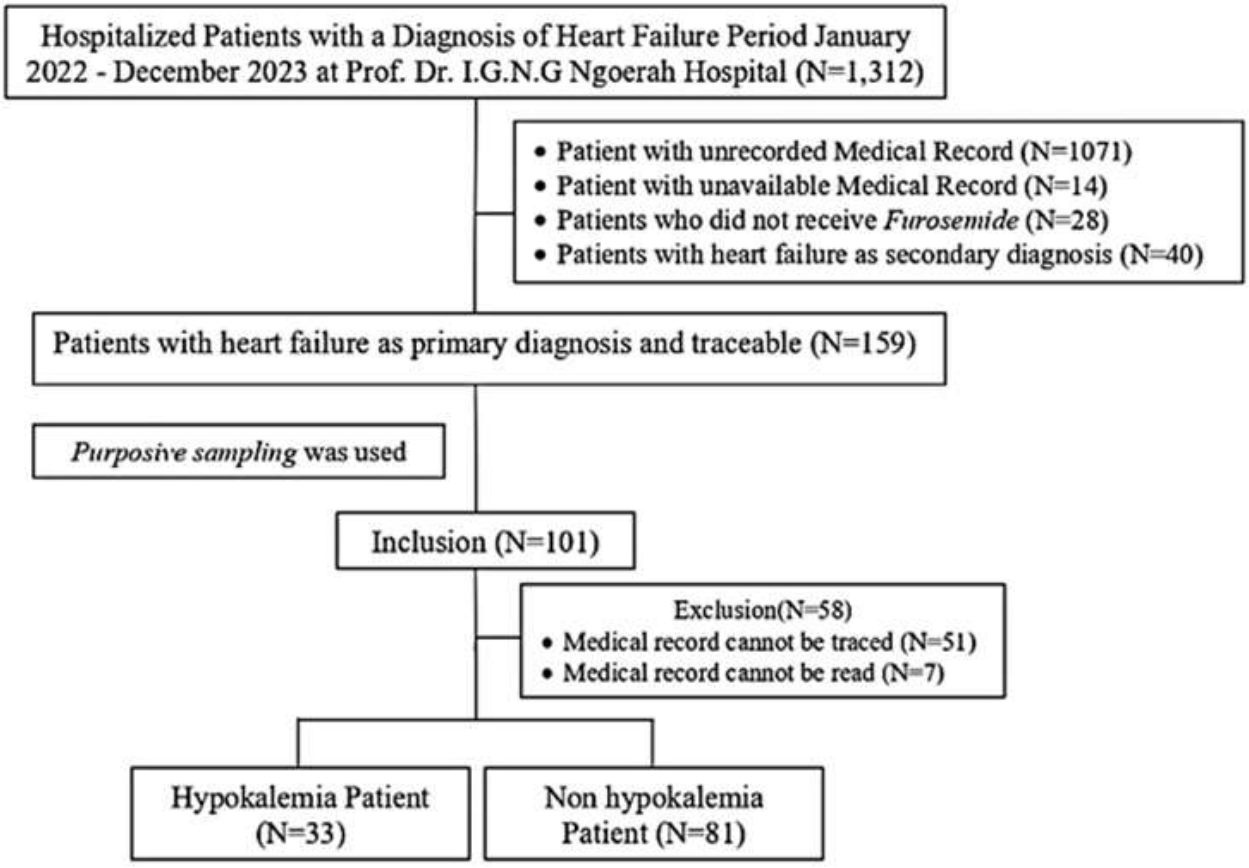

Figure 1. Flowchart of hospitalized heart failure patients receiving furosemide with available potassium data before and after hospitalization at Prof. Dr. I.G.N.G. Ngoerah Hospital from January 2022 to December 2023

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Table 1. Characteristics of heart failure patients receiving furosemide with available potassium data before and after hospitalization at Prof. Dr. I.G.N.G. Ngoerah Hospital from January 2022 to December 2023

Characteristics		Number of Patients (n total = 101)	Percentage (%)
Age (years)	15-25	1	1
	26-35	7	6.9
	36-45	18	17.8
	46-55	27	26.7
	56-65	26	25.7
	> 65	22	21.8
Gender	Male	66	65.4
	Female	35	34.6
Duration of Hospitalization	0-7 days	74	64.9
	8-14 days	29	25.4
	15-21 days	4	3.5
	> 21 days	7	6.1
Patient Status	Recovered	97	85.1
	Death	17	14.9
Diagnoses	Acute Decompensated Heart Failure	98	86
	Congestive Heart Failure	11	9.6
	Chronic Heart Failure	4	3.5
	Right Heart Failure	1	0.9
Comorbidities	Kidney	62	38
	Heart	33	20.3
	Diabetic	29	17.8
	Hypertension	24	14.7
	Dyslipidemia	15	9.2
Social History	Smoking	29	28.7
	Non-Smoking	68	67.3
	Unknown	4	4
Body Mass Index (BMI)	Underweight (less than 18.5)	6	5.9
	Normal (18.5 to less than 25)	62	61.4
	Overweight (25 to less than 30)	23	22.8
	Obesity (30 or greater)	10	9.9

Abbreviations: n: Number of Patients

Table 1 shows that the majority of patients were aged 45 years and over (74.2%) and male (65.4%). This is due to a decrease in physiological function in elderly patients (Heidenreich et al., 2022), and male patients have a higher risk of experiencing heart failure than women because women can produce the hormone estrogen which acts as a heart protector by regulating lipoprotein levels (Riyadina, 2019). Furthermore, based on the characteristics of comorbidities in patients in this study, as shown in Table 1, it is known that kidney disease is the most common comorbidity experienced by patients, namely 62 (38%), followed by heart disease as many as 33 (20.3%), and diabetes as many as 29 (17.8%) in third place. These three comorbidities are risk factors for the increased incidence of heart failure (Walli-Attaei et al. 2024; Bozkurt et al., 2025). In addition, smoking and excess weight can also contribute to an increased risk of cardiovascular disease, although they are not major risk factors. Active smokers have high levels of inflammation, cardiomyocyte injury, myocardial fibrosis, and decreased left ventricular function (Gorrdiener et al., 2022), although in this study, there were fewer patients with smoking habits (29 of 114 patients (28.7%) than non-smokers and only 10 of 114 patients (9.9%) had a BMI of 30 or greater (obesity), but this needs to be considered because patients with high BMI (tend to be at higher risk of experiencing HFrEF (Heart Failure with Reduced Ejection Fraction) (Powell et al., 2021). This is because overweight patients have a greater heart workload and are at risk of developing hypertension (Rumaisyah et al., 2023).

Potassium level data

The data obtained included 114 values of potassium levels before and after hospitalization in patients with a diagnosis of heart failure at RSUP Prof. Dr. I.G.N.G. Ngoerah, who received furosemide during the period

P-ISSN: 2406-9388
E-ISSN: 2580-8303

January 2022 to December 2023. Normality test results conducted using the Kolmogorov-Smirnov method showed a p-value > 0.05, indicating that the data were normally distributed, so it was continued with the parametric paired t-test on the value of potassium levels before and after hospitalization. Table 2 shows the results of paired t-test analysis.

Based on the results of paired t-test analysis, the p-value <0.05 was obtained, which is <0.001. This indicates a significant difference between the value of potassium levels before and after hospitalization. Next, in this study, the potassium levels of 114 patients were divided into two groups, namely the group of patients who experienced a decrease in potassium levels and the group of patients who experienced an increase in potassium levels after hospitalization.

Table 2. Results of Paired t-test analysis of potassium levels before and after hospitalization in heart failure patients receiving furosemide at Prof. Dr. I.G.N.G. Ngoerah Hospital from January 2022 to December 2023

Description	Number of patients (n total=114)	Average potassium level (mmol/L) ± SD	p-value
Before Hospitalization	114	4.3±0.9	<0.001
After Hospitalization	114	3.9±0.7	

Abbreviations: n= number of patients; SD: Standard Deviation

Table 3. Table of increased potassium levels in 30 heart failure patients receiving furosemide before and after hospitalization at Prof. Dr. I.G.N.G. Ngoerah Hospital from January 2022 to December 2023

Potassium Level Before Hospitalization (mmol/L)	Potassium Level After Hospitalization (mmol/L)	Difference Potassium Level Before and After Hospitalization (mmol/L)	Percentage Difference Potassium Level Before and After Hospitalization (%)
4.2	4.4	0.2	4.5
3.4	3.6	0.2	5.6
2.9	3.5	0.6	17.1
3.2	3.5	0.3	8.6
3.3	3.9	0.6	15.4
3.8	3.9	0.1	2.6
3.9	4	0.1	2.5
4	4.2	0.2	4.8
3.1	4.4	1.3	29.5
3.1	3.4	0.3	8.8
3.5	4.4	0.9	20.5
4.1	5	0.9	18
3.4	4	0.6	15
4.1	4.7	0.6	12.8
3.8	4.3	0.5	11.6
3.8	3.9	0.1	2.6
3.9	4.4	0.5	11.4
3.5	3.9	0.4	10.3
4.5	5.5	1	18.2
2.9	3.6	0.7	19.4
5.5	5.6	0.1	1.8
3.4	3.8	0.4	10.5
3.6	4.1	0.5	12.2
3.5	4.3	0.8	18.6
3.8	4.7	0.9	19.1
3.2	3.5	0.3	8.6
4	5.5	1.5	27.3
3.6	4.4	0.8	18.2
3.8	5.1	1.3	25.5
3.6	4.4	0.8	18.2

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Table 4. Table of decreased potassium levels in 84 heart failure patients received furosemide before and after hospitalization at Prof. Dr. I.G.N.G. Ngoerah Hospital from January 2022 to December 2023

Potassium Level Before Hospitalization (mmol/L)	Potassium Level After Hospitalization (mmol/L)	Difference Potassium Level Before and After Hospitalization (mmol/L)*	Percentage Difference Potassium Level Before and After Hospitalization (%)*
3.6	3.5	-0.1	-2.9
4.6	3.7	-0.9	-24.3
4.1	4	-0.1	-2.5
3.7	3	-0.7	-23.3
5.7	4.4	-1.3	-29.5
4.2	3.6	-0.6	-16.7
6.6	5.2	-1.4	-26.9
5	4.5	-0.5	-11.1
5.4	3.9	-1.5	-38.5
5.3	3.3	-2	-60.6
6.5	6.1	-0.4	-6.6
5	4.2	-0.8	-19
4.1	3.6	-0.5	-13.9
3.9	3	-0.9	-30
4	3.7	-0.3	-8.1
3.9	3.3	-0.6	-18.2
4.8	4.6	-0.2	-4.3
6.1	4.7	-1.4	-29.8
4.3	3.4	-0.9	-26.5
4.2	3.4	-0.8	-23.5
3.8	2.6	-1.2	-46.2
5.8	4.4	-1.4	-31.8
5.5	3.5	-2	-57.1
4.2	3.5	-0.7	-20
4.9	4.5	-0.4	-8.9
4	3.2	-0.8	-25
3.6	2.8	-0.8	-28.6
5.4	3.5	-1.9	-54.3
3.8	3	-0.8	-26.7
4.8	3.6	-1.2	-33.3
3.5	3.2	-0.3	-9.4
5.3	4.2	-1.1	-26.2
4.3	4.2	-0.1	-2.4
4.2	4.2	0	0
4.5	4.4	-0.1	-2.3
4	3.2	-0.8	-25
3.8	3.7	-0.1	-2.7
7.9	4.5	-3.4	-75.6
3.6	2.8	-0.8	-28.6
3.5	3.1	-0.4	-12.9
3.8	3.7	-0.1	-2.7
4.5	3.9	-0.6	-15.4
5.7	4.5	-1.2	-26.7
4.2	3.5	-0.7	-20
2.9	2.5	-0.4	-16
4.4	3.6	-0.8	-22.2
6.7	4.9	-1.8	-36.7
5.1	4.6	-0.5	-10.9
4.1	3.1	-1	-32.3

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Potassium Level Before Hospitalization (mmol/L)	Potassium Level After Hospitalization (mmol/L)	Difference Potassium Level Before and After Hospitalization (mmol/L)*	Percentage Difference Potassium Level Before and After Hospitalization (%)*
4.8	4.6	-0.2	-4.3
4	3.6	-0.4	-11.1
5	4.6	-0.4	-8.7
4.2	3.7	-0.5	-13.5
3.9	3.7	-0.2	-5.4
3.9	3	-0.9	-30
3.6	3.5	-0.1	-2.9
6	4.5	-1.5	-33.3
5.1	4.8	-0.3	-6.3
5.3	3.7	-1.6	-43.2
3.8	3.5	-0.3	-8.6
4.3	4.1	-0.2	-4.9
4.4	4	-0.4	-10
4.6	3.2	-1.4	-43.8
4.6	3.3	-1.3	-39.4
5.1	3.8	-1.3	-34.2
4.4	4.1	-0.3	-7.3
5.1	4	-1.1	-27.5
4.7	4.2	-0.5	-11.9
4.7	4.4	-0.3	-6.8
4.1	3.3	-0.8	-24.2
5.5	3.8	-1.7	-44.7
4.2	3.4	-0.8	-23.5
4.7	3.8	-0.9	-23.7
3.4	3.4	0	0
4.4	4.2	-0.2	-4.8
5	2.1	-2.9	-138.1
6.2	4.2	-2	-47.6
4.9	4.7	-0.2	-4.3
4.3	3.9	-0.4	-10.3
3.5	3.4	-0.1	-2.9
3.9	3.1	-0.8	-25.8
3.7	3.6	-0.1	-2.8
4	3.5	-0.5	-14.3
4.8	3.2	-1.6	-50

*: the negative value means the potassium level was decreasing after hospitalization

Table 5. Categorized potassium levels after hospitalization in heart failure patients receiving furosemide at Prof. Dr. I.G.N.G. Ngoerah Hospital from January 2022 to December 2023

Classification of Potassium Levels	Number of Patients who Increased Potassium Levels After Hospitalization (n=30)	Number of Patients who Decreased Potassium Levels After Hospitalization (n=84)
Hypokalemia (< 3,5 mmol/L)	1	32
Normal (3,5-5,1 mmol/L)	27	50
Hyperkalemia (>5,1 mmol/L)	2	2

Abbreviation: n=number of patients

The increase or decrease was calculated based on the reduction in potassium levels after hospitalization with potassium levels before hospitalization. Furthermore, the percentage difference was calculated. Patients were said to have increased potassium levels if the potassium levels after hospitalization were greater than before hospitalization. Conversely, patients were said to have decreased if the potassium levels after hospitalization were smaller than before hospitalization. Of the 114 patients, there were 30 patients who experienced an increase in potassium levels (see Table

P-ISSN: 2406-9388
E-ISSN: 2580-8303

3) and 84 patients who experienced a decrease in potassium levels after hospitalization (see Table 4).

In the group of patients who experienced increased potassium levels, the most significant percentage difference in potassium levels before and after hospitalization was 29.5%, and the smallest was 1.8%. The larger percentage difference indicates a greater increase in potassium levels after the patient was hospitalized. Increased potassium levels can be caused by the presence of comorbid diseases such as kidney disease and diabetes mellitus as well as the use of Renin Angiotensin Aldosterone System (RAAS) and Mineralocorticoid Receptor Antagonist (MRA) inhibitor drugs. This result is in line with a cohort study in Denmark, which states that the incidence of hyperkalemia was 39% during a follow-up period of 2.2 years. The study also mentioned that kidney disease and diabetes will interfere with potassium excretion and regulation. In addition, the use of RAAS inhibitors and MRA, which are standard treatments for heart failure, can also interfere with potassium excretion, causing hyperkalemia (Thomsen et al., 2018). Although heart failure patients on therapy may have increased potassium levels, several mechanisms may also lead to decreased potassium levels during treatment.

In the group of patients who experienced decreased potassium levels, the percentage difference in potassium levels before and after hospitalization was 138.1%, and the smallest was 0%. The larger percentage difference indicates a greater decrease in potassium levels. The percentage showing a value of 0% in the group of patients who experienced decreased potassium levels can occur because there is no difference in potassium levels before and after hospitalization.

Decreased potassium levels in heart failure patients after hospitalization may be due to several factors such as diuretic use, RAAS activation, and insulin use. Studies have shown that 10 to 50% of patients treated with diuretics may develop hypokalemia (Ring et al., 2022). The dose or duration of the use of Furosemide as a loop diuretic (Ferreira et al., 2020). Furosemide can increase water and electrolyte excretion through urinary excretion, inhibit Na^+, K^+, and Ca^{2+} co-transporters in the loop of henle, and induce prostaglandin-mediated and aldosterone hormones (Felker et al., 2020).

Moreover, based on Table 4, from 84 data of patients who had decreased potassium levels, 49 patients showed a decrease of >15%, and 35 patients showed a decrease of ≤ 15%. Patients with a decrease in potassium levels >15% have a higher risk of arrhythmias that can trigger sudden cardiac death in heart failure patients (Aimbudlop & Saengpait, 2023). This is caused by low K^+ concentrations that can increase heart muscle excitability and delay repolarization (Ring et al., 2022). Arrhythmias often trigger sudden cardiac death in heart failure patients (Zaher et al., 2024).

Furthermore, after the potassium levels after hospitalization were obtained, we then grouped the potassium levels into three groups: hypokalemia, normal, and hyperkalemia, as can be seen in Table 5.

Based on the results in Table 5, most patients in this study had normal potassium levels, both in the group of patients who experienced increased potassium levels after hospitalization (27 of 30 patients) and also in the group of patients who experienced decreased potassium levels after hospitalization (50 of 84). In the group of patients who experienced increased and reduced potassium levels after hospitalization, only two patients from each group had hyperkalemia, and more patients had hypokalemia (32 of 84 patients) in the group who experienced decreased potassium levels than in the group who experienced increased potassium levels after hospitalization, only 1 of 30 patients. The changes in potassium level values in patients are also influenced by several factors, such as the presence of kidney disease and the use of drugs that affect RAAS. Kidneys are responsible for 90-95% of potassium elimination, so abnormal conditions in the kidneys will interfere with the regulation of a patient's potassium levels (Ferreira et al., 2020).

One of the factors that play a role in increasing or decreasing potassium levels is the presence of kidney failure. In this study, there were more than half of the heart failure patients in this study (62 out of 114 patients) who also had comorbid kidney disorders. Moreover, for a more in-depth descriptive analysis in this study, we classified the kidney disorders experienced by patients and explored the data so that the results of Table 6 were obtained.

Based on Table 6, all heart failure patients with concomitant kidney disease experienced a decrease in potassium levels after treatment, with chronic kidney disease (CKD) stage IIIB patients experiencing the highest reduction of potassium levels. In CKD stage IIIB, decreased potassium levels often occur due to a combination of diuretic use, relatively active renal excretion, dietary changes, and the influence of other drugs. However, as the disease progresses to advanced stages (stages IV and V), the kidneys lose their ability to excrete potassium, making patients more prone to hyperkalemia than hypokalemia (Sarnowski et al., 2022). In addition to CKD patients, changes in

P-ISSN: 2406-9388
E-ISSN: 2580-8303

potassium also occur in acute kidney injury (AKI) patients, although the decrease is not as great as in CKD patients. AKI patients generally have increased serum creatinine levels and decreased urinary excretion (Kellum et al., 2021). Patients with lower glomerular filtration rate (eGFR), higher creatinine clearance, and renal failure comorbidities are more likely to develop hyperkalemia (Jun et al., 2021). In addition, patients with ACKD who have multiple bilateral cysts growing in the kidneys also have decreased potassium levels. Cysts in ACKD patients cause loss of renal tissue that triggers mitogenic signaling, changes in sodium and potassium concentrations, activation of the RAAS system, and hyperplasia of renal tubular cells (Teuwafeu et al., 2023).

Based on Table 6, all heart failure patients with concomitant kidney disease experienced a decrease in potassium levels after treatment, with chronic kidney disease (CKD) stage IIIB patients experiencing the highest reduction of potassium levels. In CKD stage IIIB, decreased potassium levels often occur due to a combination of diuretic use, relatively active renal excretion, dietary changes, and the influence of other drugs. However, as the disease progresses to advanced stages (stages IV and V), the kidneys lose their ability to excrete potassium, making patients more prone to hyperkalemia than hypokalemia (Sarnowski et al., 2022). In addition to CKD patients, changes in potassium also occur in acute kidney injury (AKI) patients, although the decrease is not as great as in CKD patients. AKI patients generally have increased serum creatinine levels and decreased urinary excretion (Kellum et al., 2021). Patients with lower glomerular filtration rate (eGFR), higher creatinine clearance, and renal failure comorbidities are more likely to develop hyperkalemia (Jun et al., 2021). In addition, patients with ACKD who have multiple bilateral cysts growing in the kidneys also have decreased potassium levels. Cysts in ACKD patients cause loss of renal tissue that triggers mitogenic signaling, changes in sodium and potassium concentrations, activation of the RAAS system, and hyperplasia of renal tubular cells (Teuwafeu et al., 2023).

Based on Table 6, it also shows that heart failure patients in this study, in addition to having comorbid kidney disorders, also had other comorbidities, called diabetes, hypertension, and dyslipidemia. The presence of additional comorbidities can affect potassium levels. Where in this study, patients with additional comorbid diabetes experienced hyperkalemia, while patients with additional comorbid cancer experienced hypokalemia. Diabetic patients are at risk of hyperkalemia due to the condition of hyporeninemic hypoaldosteronism, which causes RAAS dysfunction so that there is a decrease in aldosterone secretion by the adrenal glands, which plays a role in K^+ secretion so that potassium levels in the blood increase. In addition, uncontrolled diabetic patients also generally experience hyperosmolality, which causes K^+ ions to leave the cells so that potassium levels in the blood increase (Goia-Nishide, 2022), and patients with diabetes have a prevalence ratio of 1.38 to experience hyperkalemia compared to those without diabetes because diabetes can cause diabetic nephropathy, which can reduce kidney function and potassium excretion ability. In addition, insulin deficiency in diabetes can also disrupt the distribution of potassium between intracellular and extracellular fluids so that potassium levels in the blood tend to be high (Thomsen et al., 2018).

The presence of comorbid dyslipidemia and hypertension can also affect the patient's potassium levels. Heart failure patients who also have hypertension are at risk of experiencing increased potassium levels caused by the use of antihypertensive drugs (Rakugi et al., 2021), such as the use of RAASi drugs (ACEi, ARB, ARNi), which work by inhibiting the action of angiotensin II, thereby reducing aldosterone hormone levels, which regulate potassium secretion, thereby increasing the risk of hyperkalemia (Oktaviono & Kusumawardhani, 2020; Rakugi et al., 2021). The risk of hyperkalemia associated with renin-angiotensin-aldosterone system (RAAS) inhibition ranges from 2% to 10% in patients with hypertension (Chang et al., 2016). Besides that, patients with dyslipidemia will also tend to have altered potassium levels, as patients with central obesity, hypertriglyceridemia, low HDL-C and high fasting plasma glucose tend to have lower serum potassium levels (Sun et al., 2014).

In this study, heart failure patients were also prescribed other drugs besides furosemide, which can affect potassium levels, as seen in Table 7.

Based on Table 7, instead of furosemide, patients also received other drugs such as Angiotensin Converting Enzyme inhibitors (ACEi), Angiotensin II Receptor Blockers (ARB), beta blockers, spironolactone, potassium chloride (KSR), and insulin. Those drugs can also affect potassium levels in heart failure patients. There were 84 (73.7%) prescriptions of ACEi and 23 (20.2%) prescriptions of ARB. These two groups of drugs are angiotensin II antagonists and are commonly used in heart failure patients (Heidenreich et al., 2022). Inhibition by angiotensin II will reduce levels

P-ISSN: 2406-9388
E-ISSN: 2580-8303

of the hormone aldosterone, which regulates potassium secretion. The decrease in aldosterone levels due to ACEi and ARB is mostly offset by increased distal sodium so that potassium levels remain stable. However, in patients with renal perfusion, the proximal reabsorption becomes very strong, reducing distal sodium levels and increasing the risk of hyperkalemia (Oktaviono & Kusumawardhani, 2020).

There were 82 (71.9%) prescriptions using β-blocker drugs that inhibit β receptors in the cell membranes of various organs. This class of drugs induces hyperkalemia by suppressing the secretion of the hormone aldosterone from the adrenal cortex and decreasing the activities of the Na^+-K^+ ATPase pump so that potassium absorption by cells will also decrease (Rawal et al., 2020).

Table 7 also shows that there were 85 (74.6%) prescriptions of spironolactone. This drug works by competitively blocking the action of aldosterone, resulting in decreased sodium reabsorption and increased potassium retention (Patibandla et al., 2023). Patients with spironolactone therapy have a 10% lower risk of hypokalemia than patients with loop diuretic therapy (Ferreira et al., 2020). In addition, 33 (29%) patients received potassium supplements, namely KSR, which can increase body potassium levels (Table 7). KSR will be ionized into K^+ and Cl^- in the body. Kalium ions will then undergo reabsorption in the kidneys (Yamada & Inaba, 2021). The use of potassium supplements in patients undergoing furosemide therapy will reduce the risk of hypokalemia by 12% (Aimbudlop & Saengpait, 2023). Based on Table 7, it is also known that there are 23 (20.2%) patients using insulin. The physiological response to insulin is the activation of the Na^+-K^+ ATPase pump, which increases the absorption of K^+ into cells, thereby providing defense against hyperkalemia (Ring et al., 2022).

Table 6. Classification of comorbid kidney disease and the potassium level in 62 heart failure patients receiving furosemide before and after hospitalization at Prof. Dr. I.G.N.G. Ngoerah Hospital from January 2022 to December 2023

Classification of Comorbid Kidney Disease	Number of Patients (n total=62)	Average Potassium Before Hospitalization (mmol/L)	Average Potassium After Hospitalization (mmol/L)	Number of Patients with Hyperkalemia or Hypokalemia (n total=62)	Other Comorbidities owned by patients
Acute Kidney Injury (AKI)	32	4.2	3.7	11 Hypokalemia 0 Hyperkalemia	Diabetes Type 2 Dyslipidemia Hypertension Atrial Fibrillation
Acquired Cystic Kidney Disease (ACKD)	11	4.6	4	2 Hypokalemia 0 Hyperkalemia	Dyslipidemia Hypertension Atrial flutter Diabetes Type 2
Chronic Kidney Disease (CKD)	19				
CKD Stage II	2	4	3.9	0 Hypokalemia 0 Hyperkalemia	Diabetes Type 2 Hypertension
CKD Stage III A	6	4.8	4.1	1 Hypokalemia 1 Hyperkalemia	Diabetes Type 2 Hypertension Atrial Fibrillation
CKD Stage III B	4	6	4.5	1 Hypokalemia 1 Hyperkalemia	Diabetes Type 2
CKD Stage IV	4	4.2	4	2 Hypokalemia 0 Hyperkalemia	Diabetes Type 2 Atrial Fibrillation Paroxysmal
CKD Stage V	3	5	4.3	0 Hypokalemia 0 Hyperkalemia	Diabetes Type 2 Atrial flutter

P-ISSN: 2406-9388
E-ISSN: 2580-8303

Table 7. Drugs Used by Heart Failure Patients Who Received Furosemide During Hospitalization at Prof. Dr. I.G.N.G. Ngoerah Hospital from January 2022 to December 2023

Classification of Drugs	Number of Prescriptions	Percentage (%)
Angiotensin Converting Enzyme inhibitors (ACEi)	84	73.7
Angiotensin II Receptor Blockers (ARB)	23	20.2
Beta-Blocker	82	71.9
Spironolactone	85	74.6
Potassium Chloride (KSR)	33	29
Insulin	23	20.2

This study has several strengths, including a comprehensive evaluation of potassium level fluctuations in heart failure patients receiving furosemide therapy, a large sample size that enhances the reliability of findings, and a holistic approach that considers multiple influencing factors such as comorbidities and concurrent medications. Additionally, the use of robust statistical analyses strengthens the validity of the results. However, there are some limitations, such as the retrospective study, which relies on the availability and accuracy of medical records, and the fact that it was conducted in a single hospital, potentially limiting the generalizability of the findings. The study also does not account for the dosage of furosemide, which may influence potassium levels. Future research should focus on prospective studies to calculate the furosemide dose given to patients with renal impairment and track furosemide and potassium levels over time after dose adjustments. In addition, multicenter studies are needed to increase generalizability.

CONCLUSION

This study highlights the dynamic changes in potassium levels among heart failure patients receiving furosemide therapy during hospitalization. These findings reinforce the need for continuous potassium monitoring and individualized therapeutic strategies to reduce the risk of potassium imbalance, especially hypokalemia. Given the complexity of factors affecting potassium levels, including comorbid conditions and use of certain medications, a multidisciplinary approach is essential to optimize patient outcomes.

ACKNOWLEDGMENT

Our thanks to Ministry of Education, Culture, Research, and Technology, Directorate of Learning and Student Affairs, and Udayana University who provided research funds, so this research could be carried out properly.

FUNDING

This research was funded by Student Creativity-Exact Research (PKM-RE) 2024, Directorate of Learning and Student Affairs, Directorate General of Higher Education, Research, and Technology, Ministry of Education, Culture, Research, and Technology and Udayana University.

AUTHOR CONTRIBUTIONS

Conceptualization, R.N., K.I.A.; Methodology, R.N., K.I.A.; Software, K.I.A., N.P.I.S., N.K.A.K.; Validation, R.N.; Formal Analysis, N.P.I.S., N.K.A.K., N.K.M.A., M.S.W.; Investigation, K.I.A., N.P.I.S., N.K.A.K., N.K.M.A., M.S.W.; Resources, K.I.A., N.P.I.S., N.K.A.K., N.K.M.A., M.S.W.; Data Curration; K.I.A., N.K.A.K., N.K.M.A.; Writing - Original Draft, R.N., K.I.A., N.P.I.S., M.S.W.; Writing - Review & Editing, R.N., K.I.A., N.K.A.K., N.K.M.A.; Visualization, N.K.M.A., M.S.W.; Supervision, R.N.; Project Administration, K.I.A.; Funding Acquisition, R.N., K.I.A., N.P.I.S., N.K.A.K., N.K.M.A., M.S.W.

CONFLICT OF INTEREST

The authors declared no conflict of interest.

REFERENCES

Aimbudlop, K. & Saengpanit, D. (2023). Factors Associated with Hypokalemia after Furosemide Treatment in Hospitalized Patients with Acute Decompensated Heart Failure. *Journal of the Nephrology Society of Thailand*; *30*; 57-68.

Bozkurt, B., Ahman, T., Alexander, K., Yancy, C. & Ziaeian, B. (2025). HF STATS 2024: Heart Failure Epidemiology and Outcomes Statistics an Updated 2024 Report from the Heart Failure Society of America. *Journal of Cardiac Failure; 31*; 66-116. doi: 10.1016/j.cardfail.2024.07.001.

Chang, A. R., Sang, Y., Leddy, J., Yahya, T., Kirchner, H. L., Inker, L. A., Matsushita, K., Ballew, S. H., Coresh, J. & Grams, M. E. (2016). Antihypertensive Medications and the

Prevalence of Hyperkalemia in A Large Health System. *Hypertension*; *67*; 1181-1188. doi: 10.1161/hypertensionaha.116.07363.

DiPiro, J. S., Yee, G. C., Posey, L. M., Haines, S. T., Nolin, T. D. & Ellingrod, V. (2021). Pharmacotherapy Handbook (11th ed). USA: McGraw Hill.

Donsu, R. A., Rampengan, S. H. & Polii, N. (2020). Karakteristik Pasien Gagal Jantung Akut di RSUP Prof Dr. R. D. Kandou Periode Januari-Desember 2018. *Medical Scope Journal*; *1*; 30–37. doi: 10.35790/msj.v1i2.27463.

Ferreira, J. P., Butler, J., Rossignol, P., Pitt, B., Anker, S. D., Kosiborod, M., Lund, L. H., Bakris, G. L., Weir, M. R. & Zannad, F. (2020). Abnormalities of Potassium in Heart Failure: Jacc State-Of-The-Art Review. *Journal of The American College of Cardiology*; *75*; 2836-2850. doi: 10.1016/j.jacc.2020.04.021.

Felker, G.M., Ellison, D.H., Mullens, W., Cox, Z. L. & Testani, J. M. (2020). Diuretic Therapy for Patients with Heart Failure: JACC State-Of-The-Art Review. *Journal of the American College of Cardiology; 75*; 1178-1195. doi: 10.1016/j.jacc.2019.12.059.

Goia-Nishide, K., Coregliano-Ring, L. & Rangel, É.B. (2022). Hyperkalemia in Diabetes Mellitus Setting. *Diseases*; *10*: 1-17. doi: 10.3390/diseases10020020

Gorrdiener, J. S., Buzkova, P., Kahn, P. A, DeFilippi, C., Shah, S., Barasch, E., Kizer, J. R., Psaty, B. & Gardin, J. M. (2022). Relation of Cigarette Smoking and Heart Failure in Adults ≥ 65 Years of Age (From the Cardiovascular Health Study). *The American Journal Of Cardiology*; *168*; 90-98. doi: 10.1016/j.amjcard.2021.12.021.

Heidenreich, P. A., Bozkurt, B., Aguilar, D., Allen, L. A., Byun, J. J., Colvin, M. M., Deswal, A., Drazner, M. H., Dunlay, S. M., Evers, L. R., Fang, J. C., Fedson, S. E., Fonarow, G. C., Hayek, S. S., Hernandez, A. F., Khazanie, P., Kittleson, M. M., Lee, C. S., Link, M. S. & Yancy, C.W. (2022). AHA/ACC/HFSA Guideline for the Management of Heart Failure: A Report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines. *Circulation*; *145*; 895–1032. doi: 10.1161/CIR.0000000000001063

Jun, H.R., Kim, H., Lee, S.H., Cho, J. H., Lee, H., Yim, H. W., Yoon, K. H. & Kim, H. S. (2021). Onset of Hyperkalemia Following the Administration of Angiotensin-Converting Enzyme Inhibitor or Angiotensin II Receptor Blocker. *Cardiovascular Therapeutics*; *1*; 5935149. doi: 10.1155/2021/5935149.

Kellum, J. A., Romagnani, P., Ashuntantang, G., Ronco, C., Zarbock, A. & Anders, H. J. (2021). Acute Kidney Injury. Nature reviews. *Disease Primers*; 7; 52. doi: 10.1038/s41572-021-00284-z.

Oktaviono, Y. H. & Kusumawardhani, N. (2020). Hyperkalemia Associated with Angiotensin Converting Enzyme Inhibitor or Angiotensin Receptor Blockers In Chronic Kidney Disease. *Acta Medica Indonesiana; 52*; 74-79.

Patibandla, S., Heaton, J. & Kyaw, H. (2024). Spironolactone. StatPearls.

PERKI (Perhimpunan Dokter Spesialis Kardiovaskular Indonesia). (2020). Pedoman Tatalaksana Gagal Jantung. 2nd edn. Jakarta Barat: Perhimpunan Dokter Spesialis Kardiovaskular Indonesia.

Powell-Wiley, T. M., Poirier, P., Burke, Després, J. P., Gordon-Larsen, P., Lavie, C. J., Lear, S. A., Ndumele, C. E., Neeland, I. J., Sanders, P. & St-Onge, M. P. On Behalf of the American Heart Association Council on Lifestyle and Cardiometabolic Health; Council on Cardiovascular and Stroke Nursing; Council on Clinical Cardiology; Council on Epidemiology and Prevention; and Stroke Council (2021). Obesity and Cardiovascular Disease: A Scientific Statement From The American Heart Association. *Circulation*; *143;* 984-1010. doi: 10.1161/CIR.0000000000000973

Rawal, K.B., Chhetri, D.R., Giri, A., Girish, H.N., Luhar, M.B., Anusha, S., Ashvil, A. & Lalrinsiama, R. (2021). Metoprolol-Induced Hyperkalemia–A Case Report. *Indian Journal of Medical Sciences; 73*; 253-255. doi: 10.25259/IJMS_134_2020

Ring, L.C., Nishide, K.G. & Rangel, E.B. (2022). Hypokalemia in Diabetes Mellitus Setting. *Medicina*; *58*; 1-18. doi: 10.3390/medicina58030431

Riskesdas. (2018). Hasil Utama Riset Kesehatan Dasar (RISKESDAS). Jakarta: Kementerian Kesehatan Republik Indonesia.

Riyadina, W. (2019). Hipertensi pada Wanita Menopause. Jakarta: LIPI Press.

Rizos, C.V., Milionis, H.J. & Elisaf, M.S. (2017). Severe Hyperkalemia Following Blood Transfusions: Is There a Link?. *World Journal of Nephrology*; *6*; 53-56. doi: 10.5527/wjn.v6.i1.53.

P-ISSN: 2406-9388
E-ISSN: 2580-8303

Rosano, G.M.C., Seferovic, P., Savarese, G., Spoletini, I., Lopatin, Y., Gustafsson, F., Bayes-Genis, A., Jaarsma, T., Abdelhamid, M., Miqueo, A. G., Piepoli, M., Tocchetti, C. G., Ristić, A. D., Jankowska, E., Moura, B., Hill, L., Filippatos, G., Metra, M., Milicic, D. & Coats, A. J. S. (2022). Impact Analysis of Heart Failure Across European Countries: an ESC-HFA Position Paper. *ESC Heart Failure; 9*; 2767–2778. doi: 10.1002/ehf2.14076.

Rumaisyah, R., Fatmawati, I., Arini, F. A. & Octaria, Y. C. (2023). Association between Types of Obesity and Hypertension in Young Adults in Indonesia. *Amerta Nutrition*; *7; 24-30.* doi: 10.20473/amnt.v7i2SP.2023.24-30.

Sarnowski, A., Gama, R.M., Dawson, A., Mason, H. & Banerjee, D., (2022). Hyperkalemia in Chronic Kidney Disease: Links, Risks and Management. *International Journal of Nephrology and Renovascular Disease*; *2*; 215-228. doi: 10.2147/IJNRD.S326464.

Savarese, G., Becher, P.M., Lund, L.H., Seferovic, P., Rosano, G.M.C. & Coats, A.J. (2022). Global Burden of Heart Failure: A Comprehensive and Updated Review of Epidemiology. *European Society of Cardiology*; *118*; 3272–3287. doi: 10.1093/cvr/cvac013.

Sun, K., Su, T., Li, M. & Xu, B. (2014). Serum potassium level is associated with metabolic syndrome: A population-based study. *Clinical Nutrition; 2014*; 521-527. doi: 10.1016/j.clnu.2013.07.010.

Teuwafeu, D. G., Dongmo, A., Fomekong, S. D., Amougou, M., Mahamat, M., Nono, A., Kaze, F. F. & Ashuntantang, G. (2023). Acquired Cystic Kidney Disease in Patients On Maintenance Hemodialysis, Prevalence and Associated Factors: A Cross-Sectional Study. *The Pan African Medical Journal*; 45; 1-10. doi: 10.11604/pamj.2023.45.175.31773.

Thomsen, R. W., Nicolaisen, S. K., Hasvold, P., Garcia-Sanchez, R., Pedersen, L., Adelborg, K., Egfjord, M., Egstrup, K. & Sørensen, H. T. (2018). Elevated Potassium Levels in Patients with Congestive Heart Failure: Occurrence, Risk Factors, and Clinical Outcomes: A Danish Population-Based Cohort Study. *Journal of the American Heart Association; 7*; 1-15. doi: 10.1161/JAHA.118.008912.

Walli-Attaei, M., Joseph, P., Johansson, I., Sliwa, K., Lonn, E., Maggioni, A. P., Mielniczuk, L., Ross, H., Karaye, K., Hage, C., Pogosova, N., Grinvalds, A., McCready, T., McMurray, J., Yusuf, S. & G-CHF investigators. (2024). Characteristics, Management, And Outcomes in Women And Men With Congestive Heart Failure In 40 Countries At Different Economic Levels: An Analysis From The Global Congestive Heart Failure (G-CHF) Registry. *Lancet Global Health*; *12*; e396-e405. doi: 10.1016/S2214-109X(23)00557-0.

Yamada, S. & Inaba, M. (2021). Potassium Metabolism and Management in Patients With CKD. *Nutrients; 13*; 1-19. doi: 10.3390/nu13061751.

Zaher, W., Della Rocca, D. G., Pannone, L., Boveda, S., de Asmundis, C., Chierchia, G. B. & Sorgente, A. (2024). Anti Arrhythmic Effects of Heart Failure Guideline-Directed Medical Therapy and Their Role in the Prevention of Sudden Cardiac Death: From Beta-Blockers to Sodium-Glucose Co-transporter 2 Inhibitors and Beyond. *Journal of Clinical Medicine*; *13*; 1-16. doi: 10.3390/jcm13051316.

P-ISSN: 2406-9388
E-ISSN: 2580-8303