Al-Rafidain J Med Sci. 2025;9(2):315-320.
DOI: https://doi.org/10.54133/ajms.v9i2.2542

AJMS
Online ISSN (2789-3219)

Research Article

The Physiological Role of BNP and Galectin-3 in Predicting Pacing Dependency in Patients with Cardiovascular Implantable Electronic Devices

Khalid Saud Salih*
Department of Pharmacology and Toxicology, College of Pharmacy, Tikrit University, Tikrit 34001, Iraq
Received: 30 September 2025; Revised: 14 November 2025; Accepted: 26 November 2025

Abstract

Background: Pacemaker dependency is a critical consideration in patients with cardiovascular implantable electronic devices (CIEDs). ***Objective***: To evaluate the predictive value of B-type natriuretic peptide (BNP) and galectin-3 in forecasting pacing dependency in patients with CIED. ***Methods***: One hundred patients with CIEDs were classified as pacing dependent (n=39) or non-dependent (n=61) based on established criteria. Associations with clinical and biomarker variables were analyzed using univariate and multivariate logistic regression. Receiver operating characteristic (ROC) curves assessed the predictive value of BNP and galectin-3. ***Results***: Pacing dependency was significantly associated with longer CIED duration (≥5 years), chronic kidney disease, and second- or third-degree atrioventricular block. Patients with severe left ventricular dysfunction were more likely to be pacing dependent. Median BNP and galectin-3 levels were significantly higher in the pacing-dependent group (269pg/ml and 22ng/ml, respectively). Multivariate analysis identified CIED duration >5 years (OR=3.28), CKD (OR=3.47), NYHA class III (OR=3.88), NYHA class IV (OR=5.33), BNP >160pg/ml (OR=6.23), and galectin-3 >16ng/ml (OR=2.12) as independent predictors of pacing dependency. The ROC analysis showed that BNP (AUC=0.836) and galectin-3 (AUC=0.715) were good predictors, and they were even better when used together (AUC=0.912, sensitivity=87%, specificity=85%). ***Conclusions***: BNP and galectin-3 are valuable biomarkers for predicting pacing dependency in patients with CIEDs, and they provide a robust model for identifying patients at higher risk of pacing dependency when combined with clinical parameters.

Keywords: BNP, Chronic kidney disease, Galectin-3, Pacemaker dependency.

الدور الفيزيولوجي للبيبتيد المدر للصوديوم من النوع B و غالاكتين-3 في التنبؤ بالاعتماد على الناظمة القلبية لدى مرضى الأجهزة القلبية الإلكترونية المزروعة

الخلاصة

الخلفية: يُعدّ الاعتماد على الناظمة القلبية عاملًا مهمًا لدى مرضى الأجهزة القلبية الإلكترونية المزروعة، ويسهم تحديد المؤشرات السريرية والكيميائية الحيوية المرتبطة به في تحسين المتابعة والعلاج. **الهدف**: تقييم الدور التنبئي لكلٍّ من البيبتيد المدر للصوديوم من النوع B وغالاكتين-3 في الاعتماد على الناظمة القلبية لدى المرضى الحاملين لأجهزة قلبية مزروعة. **الطرائق**: شملت الدراسة 100 مريض بأجهزة قلبية إلكترونية مزروعة، صنّفوا إلى معتمدين على الناظمة (39) وغير معتمدين (61). جرى تحليل العوامل السريرية والدموية باستخدام التحليل اللوجستي الأحادي والمتعدد، مع استخدام منحنى ROC لتقييم القيمة التنبؤية للواسمات الحيوية. **النتائج**: ارتبط الاعتماد على الناظمة بطول مدة الجهاز (≥5 سنوات)، ومرض الكلى المزمن، والحصار الأذيني البطيني المتقدم، وضعف البطين الأيسر، والدرجة الوظيفية الثالثة أو الرابعة حسب تصنيف جمعية نيويورك لأمراض القلب. كانت مستويات البيبتيد المدر للصوديوم من النوع B وغالاكتين-3 أعلى بشكل ملحوظ لدى المعتمدين على الناظمة. أظهر التحليل المتعدد أن مدة الجهاز، ومرض الكلى المزمن، ودرجات جمعية نيويورك لأمراض القلب المتقدمة، والبيبتيد المدر للصوديوم من النوع Bاكثر من 160بيكوغرام/مل، و وغالاكتين- 3اقل من 16نانوغرام/مل عوامل مستقلة للتنبؤ بالاعتماد على الناظمة. أظهر تحليل ROC دقة جيدة للـ(AUC) لكل من البيبتيد المدر للصوديوم من النوع B وغالاكتين-3 مع أداء متميز عند دمجهما(AUC = 0.912) ؛ الحساسية 87%، النوعية 85%. **الاستنتاجات**: يشكّل كلٌّ من البيبتيد المدر للصوديوم من النوع B وغالاكتين-3 واسمين حيويين فعّالين للتنبؤ بالاعتماد على الناظمة القلبية، كما يعزز دمجهما مع البيانات السريرية القدرة على تحديد المرضى الأكثر عرضة لذلك.

* ***Corresponding author***: Khalid Saud Salih, Department of Pharmacology and Toxicology, College of Pharmacy, Tikrit University, Tikrit 34001, Iraq; Email: dr.kh.fa.ha@tu.edu.iq
Article citation: Salih KS. The Physiological Role of BNP and Galectin-3 in Predicting Pacing Dependency in Patients with Cardiovascular Implantable Electronic Devices. *Al-Rafidain J Med Sci.* 2025;9(2):315-320. doi: https://doi.org/10.54133/ajms.v9i2.2542

INTRODUCTION

Pacing dependency in individuals with cardiovascular implantable electronic devices (CIEDs) denotes the inadequacy or complete absence of intrinsic cardiac rhythm, which may precipitate bradycardia-related manifestations or cardiac arrest upon the discontinuation of ventricular pacing [1,2]. The prevalence of pacemaker dependency exhibits considerable variability across various studies, predominantly attributable to discrepancies in definitions, methodologies employed for testing, and the characteristics of patient cohorts. In a comprehensive investigation encompassing 3,638 participants with an average follow-up duration of 4.8 years, pacemaker dependency was documented in merely 2.1% of the total cohort. Nevertheless, the prevalence of dependency exhibited significant variability contingent upon the underlying rationale for pacing. Individuals diagnosed with atrioventricular block (AVB) showed a markedly elevated prevalence of dependency (3.5%) in comparison to those

diagnosed with sick sinus syndrome (SSS) (0.6%) or atrial fibrillation associated with bradycardia (0.3%) [3]. A multitude of risk factors have been recognized as contributing to the emergence of pacemaker dependency. The underlying clinical indication for pacing arguably constitutes the most critical determinant, with AVB presenting a considerably heightened risk in contrast to SSS or atrial fibrillation with bradycardia [4]. Within the category of atrioventricular block (AVB), higher-degree blocks (Mobitz type II and complete heart block) are correlated with an augmented risk of dependency when juxtaposed with lower-degree variants [5]. Age is another significant variable, with certain studies indicating escalated rates of dependency among older populations, potentially reflecting age-associated degeneration of the conduction system [6]. Additional determinants that may affect the onset of dependency encompass the duration of pacing, the proportion of ventricular pacing, and potentially the anatomical site of ventricular lead placement. Some empirical evidence intimates that right ventricular apical pacing might facilitate dependency through deleterious electrical and mechanical remodeling; however, this correlation necessitates further scholarly inquiry [7]. There may also be genetic factors that play a role, since conduction disorders tend to run in families. These factors may have genetic components that affect both the initial need for pacing and the patterns of dependency that develop over time [8]. Conversely, the potential utility of serum biomarkers as prognostic indicators of pacing dependency has garnered minimal scholarly attention. Cardiac natriuretic peptides (NPs), specifically atrial NP (ANP) and B-type NP (BNP), are authentic hormones synthesized and secreted by cardiomyocytes, exerting a plethora of systemic influences, in addition to various paracrine and autocrine activities pertinent to cardiac function, thereby contributing to cardiovascular homeostasis. Beyond their natriuretic, vasorelaxant, metabolic, and antiproliferative systemic functions, NPs impede cardiac hypertrophy, fibrosis, arrhythmias, and cardiomyopathies, counteracting the onset and progression of heart failure [9]. Galectin-3 (Gal-3), conversely, represents the singular chimera-type entity within the lectin family, exhibiting widespread expression across human tissues and functioning as a galactoside-binding protein implicated in numerous biological processes, including the regulation of cell–cell and cell–matrix interactions, cellular adhesion, proliferation, apoptosis, immunity, and inflammation [10]. In the context of heart failure pathology, Gal-3 exerts a biological influence predominantly through mechanisms of fibrosis and inflammation [11]. Gal-3 facilitates pathological remodeling and the progression of fibrosis primarily by promoting fibroblast proliferation and collagen deposition; thus, it has been designated as a “culprit” biomarker in heart failure, in contrast to “bystander” biomarkers such as BNP [12]. Based on these data, the present study aimed to evaluate the predictive value of BNP and galectin-3 in forecasting pacing dependency in patients with CIED.

METHODS

Study design and participants

This is a prospective cross-sectional study including 100 adult patients carrying CIEDs at Ibn Al-Baitar Hospital during the period from August 2024 to August 2025. Pacing dependency was defined as an absence of intrinsic rhythm ≥ 30 bpm after lowering the pacing rate to 30 bpm for at least 10 seconds or after transient inhibition of pacing therapy. The study protocol was approved by the Iraqi Council of Medical Specializations. Patients with epicardial pacemaker implantation were excluded from the study.

Data collection

Demographic variables encompassing age, sex, duration of CIED utilization, and medical history were examined. Chronic kidney disease (CKD) classified as stage 3 or higher was identified based on at least two assessments of estimated glomerular filtration rates (eGFR) calculated using the Modification of Diet in Renal Disease formula, yielding values beneath 60 mL/min per 1.73 m^2, with a minimum interval of three months between assessments. Clinical attributes included the rationale for pacemaker (PM) implantation, the nature of ventricular pacing, left ventricular (LV) functionality, and the operational mode of the PM. The evaluation of LV function was conducted utilizing transthoracic echocardiography (Vivid S6/ USA). Measurements and calculations adhered to the guidelines established by the American Society of Echocardiography. The left ventricular ejection fraction (LVEF) was quantified employing the modified Simpson method.

Ethical approval

Ethical approval was obtained from the College of Pharmacy - Tikrit University Scientific and Ethical committees. All procedures involving human participants performed in the present study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Declaration of Helsinki and its later amendments. Verbal consent was obtained from all patients before starting data collection and after explaining the details of the study and assuring confidentiality.

Statistical analysis

All data were systematically documented in Microsoft Excel and subsequently analyzed using the Statistical Package for the Social Sciences (SPSS) software, version 25.0. Continuous variables were represented as mean ± standard deviation (SD) and were analyzed using the independent t-test (parametric) or represented as median (IQR) and were analyzed using the Mann-Whitney U test (non-parametric), whereas categorical variables were presented as frequency and

percentage, with analysis conducted via Chi-square tests. A multivariate logistic regression analysis was executed to ascertain the independent predictors of pacing dependence. From this analysis, the odds ratio (OR) along with the corresponding 95% confidence interval (CI) was computed. The receiver operating characteristic (ROC) curve was utilized to assess the predictive capacity of B-type natriuretic peptide (BNP) and galectin-3 in relation to anticipating pacing dependency. A p-value of 0.05 or less was deemed statistically significant.

RESULTS

According to the established criteria for pacing dependency, 39 patients (39%) were classified as pacing-dependent, whereas 61 patients (61%) were considered pacing-independent. Table 1 shows the association between various demographic and clinical characteristics and pacing dependency among patients with CIEDs. The mean age did not differ significantly between pacing-dependent and non-dependent groups (65.49 ± 17.84 *vs*. 64.67 ± 15.92 years, p= 0.811), and no significant association was found with sex (p= 0.493).

Table 1: Association of demographic characteristics with pacing dependency

Variables		Pacing dependency		*p*-value
		No (n=61)	Yes (n=39)	
Sex	Male	27	20	0.493
	Female	34	19	
Duration of CIEDs (year)	<5	37	15	0.030
	≥5	24	24	
Past medical history	Diabetes	15	15	0.140
	Hypertension	29	20	0.715
	Dyslipidemia	20	19	0.111
	Ischemic heart disease	7	10	0.066
	Chronic kidney disease	3	9	0.010
Age (year)	(mean±SD)	64.67±15.92	65.49±17.84	0.811

A significant relationship was observed between pacing dependency and the duration of CIED implantation, with patients having devices for ≥5 years being more likely to be pacing dependent compared to those with devices for <5 years (61.54% *vs*. 38.46%, p= 0.030). Chronic kidney disease (CKD) was the only comorbidity that was significantly linked to pacing dependency. The pacing-dependent group had a higher prevalence of CKD (23.8% vs. 4.92%, p= 0.010). Other conditions, including diabetes mellitus, hypertension, dyslipidemia, and ischemic heart disease, were not significantly associated with pacing dependency, although the association with ischemic heart disease approached statistical significance (p= 0.066). The indication for CIED implantation was significantly associated with pacing dependency (p= 0.008). Specifically, patients with second- or third-degree AVB comprised a larger proportion of the pacing-dependent group (66.67%) compared to the non-dependent group (34.43%), while those with sinus node dysfunction (SSS), atrial fibrillation (AF), and ventricular tachycardia (VT) were more prevalent in the non-dependent group. Left ventricular (LV) function also showed a significant association (p= 0.010); patients with severe LV dysfunction were more likely to be pacing dependent (17.95% vs. 1.64%). Functional status, as measured by the New York Heart Association (NYHA) classification, was likewise associated with pacing dependency (p= 0.009), with a greater proportion of pacing-dependent patients in NYHA classes III and IV. In contrast, pacemaker mode (DDD, VDD, or VVI) did not demonstrate a statistically significant relationship with pacing dependency (p= 0.145). Biomarker analysis revealed that median B-type natriuretic peptide (BNP) levels were significantly higher in pacing-dependent patients compared to non-dependent ones (269.0 pg/ml *vs*. 146.0 pg/ml, p< 0.001). Similarly, median galectin-3 levels were elevated in the pacing-dependent group (22.0 ng/ml *vs*. 16.0 ng/ml, p< 0.001), as shown in Table 2.

Table 2: Association of clinical characteristics with pacing dependency

Variables		Pacing dependency		*p*-value
		No (n=61)	Yes (n=39)	
Indication for CIEDs	Second or third AVB	21	26	0.008
	Sick sinus syndrome	17	6	
	Atrial Fibrillation	12	6	
	Ventricular Tachycardia	11	1	
LV function	Normal	51	25	0.010
	Mild-Moderate dysfunction	9	7	
	Severe dysfunction	1	7	
NYHA classification	II	2	17	0.009
	III	18	27	
	IV	19	17	
Mode of pacemaker	DDD	30	15	0.145
	VDD	21	11	
	VVI	10	13	
BNP (pg/ml)	Median (IQR)	146.0 (70-372)	269.0 (132-576)	<0.001
Galectin-3 (ng/ml)	Median (IQR)	16.0 (6.38-38.0)	22.0 (5.7-96.0)	<0.001

In order to find the independent factors that predict pacing dependence, a multivariate analysis model was performed. Only factors that had *a p-value* ≤ 0.1 in univariate analyses were entered into this model. Each continuous variable was categorized into two categories with an appropriate cutoff value. The result is depicted in Table 3.

Table 3: Multivariate analysis

Variables		Independent (n=61)	Dependent (n=39)	*p*-value	OR (95% CI)
Duration (year)	≤5	37	15	0.019	3.28(1.12-4.71)
	>5	24	24		
Ischemic heart disease	No	54	29	0.256	2.03(0.42-25.42)
	Yes	7	10		
Chronic kidney disease	No	58	30	0.011	3.47(1.27-7.18)
	Yes	3	9		
Indication for CIEDs	Second or third AVB	21	26	0.043	0.39(0.09-1.69)
	Sick sinus syndrome	17	6	0.086	0.27(0.06-1.2)
	Atrial Fibrillation	12	6	0.109	0.39(0.09-1.69)
	Ventricular Tachycardia	11	1	0.013	0.11(0.08-1.67)
LV function	Normal	51	25	0.132	4.69(0.88-16.32)
	Mild-Moderate dysfunction	9	7	0.316	2.0(0.52-7.7)
	Severe dysfunction	1	7	0.063	4.69(0.88-16.32)
NYHA classification	II	2	17	0.060	5.33(1.85-21.98)
	III	18	27	0.024	5.33(1.85-21.98)
	IV	19	17	0.001	3.88(1.34-61.13)
BNP (pg/ml)	≤160	33	5	0.001	6.23(2.69-39.64)
	>160	28	34		
Galectin-3 (ng/ml)	≤16	31	8	0.014	2.12(1.85-21.98)
	>16	30	31		

Each CIED duration (OR= 3.28, 95% CI= 1.12-4.71, *p*=0.019), CKD (OR= 3.47, 95% CI= 1.27-7.18, *p*=0.011), second or third AVB (*p*= 0.043), NYHA III (OR= 3.88, 95% CI= 1.34-61.13, *p*= 0.024), and NYHA IV (OR= 5.33, 95% CI= 1.85-21.98, *p*= 0.001) BNP > 160 pg/ml (OR= 6.23, 95% CI= 2.69-39.64, *p*= 0.001) and galectin-3 > 16 ng/ml (OR= 2.12, 95% CI= 1.85-21.98) were independent factors for prediction of independence. Receiver operating characteristic (ROC) curve was used to explore the predictive value of BNP and galectin in anticipating pacing dependency. For BNP, the AUC was 0.836, 95% CI= 0.759-0.914, *p*<0.001. The sensitivity and specificity of the test at a cutoff value of BNP= 166 pg/ml were 87% and 64%, respectively. For galectin-3, the AUC was 0.715, 95% CI= 0.605-0.824, *p*< 0.001. The sensitivity and specificity of the test at a cutoff value of BNP= 16.5 ng/ml were 77% and 56%, respectively (Figure 1).

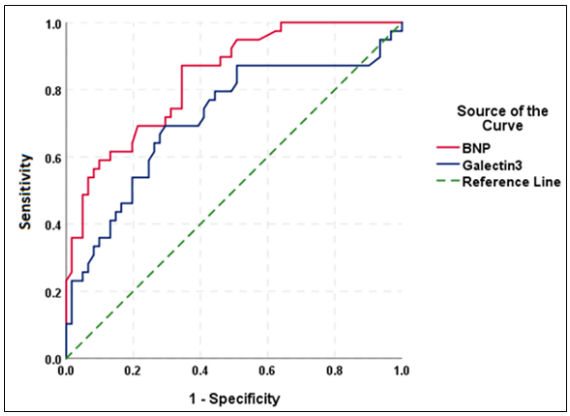

Figure 1: ROC curve for BNP and galectin-3 as predictors for pacing dependency in patients carrying CIEDs.

For the combination of BNP and galectin-3, the AUC was 0.912, 95% CI= 0.857-0.966, *p*<0.001. The sensitivity and specificity of the test were 87% and 85%, respectively (Figure 2).

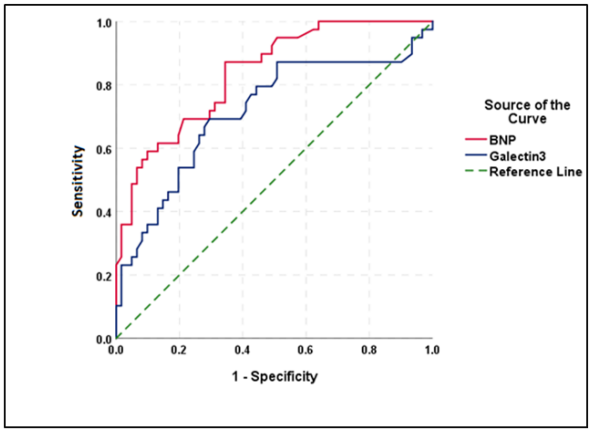

Figure 2: ROC curve for the combination of BNP and galectin-3 as predictors for pacing dependency in patients carrying CIEDs.

DISCUSSION

Various investigations conducted globally have identified distinct independent predictors associated with pacing dependency. In a study conducted in the Netherlands, multivariate analysis revealed a significant correlation between pacing dependency and the presence of either second- or third-degree atrioventricular (AV) block at the time of implantation (OR= 19.9), atrial fibrillation at the time of implantation (OR= 2.15), LVEF ≤ 30% (OR= 2.06), CKD (OR= 1.86), and a follow-up duration exceeding five years post-implantation (OR= 3.29) [1]. A meta-analysis conducted by Steyers *et al.* [13] characterized the associated factors identified by multiple researchers who have investigated this phenomenon in patients receiving implants for conductive disorders subsequent to cardiac surgery. These factors encompassed postoperative complete

atrioventricular block (AVB), preoperative first-degree AVB, preoperative left bundle branch block, syncope, and a body mass index (BMI) of 28.5 kg/m² or greater. Through the application of multivariate analysis, Sonou *et al*. [14] illustrated that female gender (OR= 3.28, 95% CI= 1.32-8.64, *p*= 0.012), preoperative complete AVB (OR= 0.11, 95% CI= 0.03-0.32, *p*= 0.001), and a duration of less than twelve months (OR= 0.22, 95% CI= 0.05-0.77) were significantly correlated with pacing dependency. The discrepancies in independent predictors of pacing dependency across studies can be explained by differences in study populations, definitions, methodologies, and clinical settings. Variations in patient characteristics—such as underlying heart disease, indication for device implantation, and comorbidities like chronic kidney disease or heart failure—can significantly influence outcomes. Additionally, each study may use different definitions and timeframes for assessing pacing dependency, leading to varied interpretations. The significant association of these factors with pacing dependency could be explained in different aspects. For example, CKD promotes electrolyte disturbances (hyperkalemia, hypocalcemia, and hypomagnesemia) that adversely affect cardiac conduction tissue excitability and impulse propagation. These metabolic abnormalities can suppress sinus node automaticity and impair atrioventricular conduction, potentially leading to increased pacing dependency [15]. Advanced AVB typically reflects structural damage to the conduction system from processes such as fibrosis, degeneration, ischemia, or infiltration. Unlike functional conduction disturbances that might be reversible, these structural abnormalities tend to be permanent and progressive [16]. Advanced heart failure (NYHA IV) is characterized by excessive neurohormonal activation (elevated catecholamines, renin-angiotensin-aldosterone system activation, and elevated natriuretic peptides), which may directly suppress sinus node function and impair conduction through various mechanisms [17]. In the present study, each of BNP and galectin-3 was significantly elevated in patients with pacing dependency compared with those with pacing independency, and the combination of both markers had an excellent AUC (0.912), with the sensitivity and specificity of the test being 87% and 85%, respectively. To the best of our knowledge, the only previous study that investigated the serum biomarkers for predicting pacing independency was that by Grimm *et al*. [1], which found that BNP > 150 pg/mL is independently associated with pacing dependency (OR= 2.12; 95% CI: 1.16–3.97, *p*= 0.02). On the other hand, studies have demonstrated that patients with ventricular rate modulated pacing (VVI) modes exhibit increased BNP levels over time (BNP ratio of 1.54±0.3 after 3 months), whereas those with Dual Chamber Rate Adaptive (DDDR) pacing show decreased BNP levels (ratio 0.38±0.17). The reason for this difference is that atrioventricular synchrony is lost during VVI pacing, which lowers cardiac output and raises stress on the ventricular wall. [18]. As VVI was more common in the pacing-dependency group in the present study, this can explain, in part, the high level of BNP in those patients. Furthermore, pacing can lead to electromechanical dyssynchrony, resembling the pattern observed in left bundle branch block. This dyssynchrony causes abnormal septal motion, reduced left ventricular ejection fraction, and ultimately promotes the development of pacing-induced cardiomyopathy. The higher BNP levels in patients who need pacing are most likely a result of this abnormal remodeling process and the resulting problems with blood flow [19]. Galectin-3 functions as a key mediator between inflammation and fibrosis, with elevated levels reflecting ongoing inflammatory activity in cardiac tissue. A previous study indicated that galectin-3 promotes the conversion of fibroblasts to myofibroblasts and enhances the secretion of pro-inflammatory cytokines, creating a vicious cycle of inflammation and fibrosis that predisposes to conduction system disease and pacing dependency [20]. Moreover, galectin-3 may help identify patients at risk for atrial high-rate episodes (AHREs**).** This is particularly relevant in pacing-dependent patients, who may be more vulnerable to atrial arrhythmias due to underlying structural heart disease [21]. BNP and galectin-3 reflect distinct but interconnected pathological processes in cardiac remodeling. While BNP primarily represents hemodynamic stress and volume overload, galectin-3 reflects inflammatory-mediated fibrotic transformation. Their simultaneous elevation in pacing-dependent patients suggests the coexistence of both mechanical stress and structural remodeling, providing a more comprehensive picture of the underlying myocardial pathology. Felker *et al*. [22] demonstrated that patients with concordant elevation of both biomarkers have worse outcomes than those with elevation of only one marker, highlighting the potential synergistic effect of these pathways in driving progression of the disease. This study has several limitations that should be acknowledged. First, the sample size was relatively small and drawn from a single center, which may limit the generalizability of the findings to broader populations. Second, the cross-sectional design restricts the ability to establish causal relationships between biomarker levels and the development of pacing dependency. Additionally, biomarker measurements were performed at a single time point, which may not reflect dynamic changes over time. Lastly, device-related factors such as pacing percentage and lead parameters were not analyzed in detail and could provide further insights in future studies. Prospective, longitudinal studies with larger, diverse cohorts are needed to validate and expand upon these findings.

Conclusion

Collectively this study demonstrates that pacing dependency in patients with CIEDs is significantly associated with both clinical and biochemical parameters. Key independent predictors include prolonged CIED implantation duration, presence of

chronic kidney disease, advanced NYHA functional class, and second- or third-degree atrioventricular block. Importantly, elevated levels of BNP and galectin-3 were found to be strong and independent predictors of pacing dependency. ROC analysis further confirmed the high predictive accuracy of BNP and galectin-3, particularly when used in combination. These findings suggest that integrating biomarker assessment with clinical evaluation may enhance risk stratification and guide follow-up strategies in patients with CIEDs. Thus, measurement of BNP and galectin-3 levels should be considered in the clinical evaluation of patients with CIEDs, particularly for those at risk of developing pacing dependency.

Conflict of interests

The author declares no conflict of interest.

Funding source

The author did not receive any source of funds.

Data sharing statement

Supplementary data can be shared with the corresponding author upon reasonable request.

REFERENCES

1. Grimm W, Grimm K, Greene B, Parahuleva M. Predictors of pacing-dependency in patients with cardiovascular implantable electronic devices. *Cardiol J.* 2021;28(3):423-430. doi: 10.5603/CJ.a2019.0088.
2. Abdullah HA, Al-Mossawi A, Al-Iqabby KAI. Prevalence and predictors of pacemaker dependency: Data from a cardiac centre registry in Iraq. *Cor et Vasa.* 2023;65(5):735-739. doi: 10.33678/cor.2023.022.
3. Lelakowski J, Majewski J, Bednarek J, Małecka B, Zabek A. Pacemaker dependency after pacemaker implantation. *Cardiol J.* 2007;14(1):83-86.
4. Kusumoto FM, Schoenfeld MH, Barrett C, Edgerton J, Ellenbogen K, Gold M, et al. 2018 ACC/AHA/HRS Guideline on the Evaluation and Management of Patients With Bradycardia and Cardiac Conduction Delay: Executive Summary: A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines, and the Heart Rhythm Society. *J Am Coll Cardiol.* 2019;74(7):932-987. doi: 10.1016/j.jacc.2018.10.043.
5. Epstein AE, DiMarco JP, Ellenbogen KA, Mark Estes NA, Freedman RA, Gettes LS, et al. ACC/AHA/HRS 2008 Guidelines for Device-Based Therapy of Cardiac Rhythm Abnormalities: A report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Writing Committee to Revise the ACC/AHA/NASPE 2002 Guideline Update for Implantation of Cardiac Pacemakers and Antiarrhythmia Devices): developed in collaboration with the American Association for Thoracic Surgery and Society of Thoracic Surgeons. *Circulation.* 2008;117(21):e350-e408. doi: 10.1161/CIRCUALTIONAHA.108.189742.
6. Nowak B, Misselwitz B; Expert committee 'Pacemaker', Institute of Quality Assurance Hessen, et al. Do gender differences exist in pacemaker implantation?--results of an obligatory external quality control program. *Europace.* 2010;12(2):210-215. doi: 10.1093/europace/eup312.
7. Sweeney MO, Hellkamp AS, Ellenbogen KA, Greenspon AJ, Freedman RA, Lee KL, et al. Adverse effect of ventricular pacing on heart failure and atrial fibrillation among patients with normal baseline QRS duration in a clinical trial of pacemaker therapy for sinus node dysfunction. *Circulation.* 2003;107(23):2932-2937. doi: 10.1161/01.CIR.0000072769.17295.B1.
8. Schott JJ, Alshinawi C, Kyndt F, Probst V, Hoorntje TM, Hulsbeek M, et al. Cardiac conduction defects associate with mutations in SCN5A. *Nat Genet.* 1999;23(1):20-21. doi: 10.1038/12618.
9. Sarzani R, Allevi M, Di Pentima C, Schiavi P, Spannella F, Giulietti F. Role of cardiac natriuretic peptides in heart structure and function. *Int J Mol Sci*. 2022;23(22):14415. doi: 10.3390/ijms232214415.
10. Blanda V, Bracale UM, Di Taranto MD, Fortunato G. Galectin-3 in cardiovascular diseases. *Int J Mol Sci.* 2020;21(23):9232. doi: 10.3390/ijms21239232.
11. Suthahar N, Meijers WC, Silljé HHW, Ho JE, Liu FT, de Boer RA. Galectin-3 activation and inhibition in heart failure and cardiovascular disease: An update. *Theranostics.* 2018;8(3):593-609. doi: 10.7150/thno.22196.
12. Bošnjak I, Selthofer-Relatić K, Včev A. Prognostic value of galectin-3 in patients with heart failure. *Dis Markers.* 2015;2015:690205. doi: 10.1155/2015/690205.
13. Steyers CM 3rd, Khera R, Bhave P. Pacemaker dependency after cardiac surgery: A Systematic review of current evidence. *PLoS One.* 2015;10(10):e0140340. doi: 10.1371/journal.pone.0140340.
14. Sonou D, Adikpéto F, Hounkponou M, Dossou C, Bokodaho M, Dossou D, et al. Study of Pacing Dependency in Patients with a Cardiac Implanted Electronic Device at the National Teaching Hospital of Cotonou in 2023. *World J Cardiovasc Dis*. 2025;15:374-381. doi: 10.4236/wjcd.2025.157032.
15. Kiuchi MG, Chen S. Predictors for atrial fibrillation onset in CKD patients with pacemaker. *Nephrol Renal Dis*. 2017;2(3)1-6. doi: 10.15761/NRD.1000125.
16. Ruiz-Hernandez PM, Gonzalez-Torrecilla E, Gutierrez-Ibañez E, Gonzalez-Saldivar H, Bruña V, Loughlin G, et al. Predictors of pacemaker dependency in patients implanted with a pacemaker after transaortic valve replacement. *Int J Cardiol Heart Vasc*. 2020;31:100654. doi: 10.1016/j.ijcha.2020.100654.
17. Grimm W, Erdmann B, Grimm K, Kreutz J, Parahuleva M. Prognosis of pacing-dependent patients with cardiovascular implantable electronic devices. *Herzschrittmacherther Elektrophysiol*. 2024;35(1):39-45. doi: 10.1007/s00399-024-00996-1.
18. Dehnavi AM, Fakhrpour A, Tavakoli MB, Nikoo MH. Investigation of the bnp level changes in blood stream in different modes and lead locations after pacemaker implementation. *J Med Signals Sens*. 2012;2(1):38-41.
19. Qui N, Wong Y, Jin Y, Liu X, Chen X. Randomized trial of left bundle branch pacing vs. right ventricular pacing in ventricular pacing-dependent patients. *Heart Rhythm*. 2025;22(4):S787-S788. doi: 10.1016/j.hrthm.2025.03.1895.
20. Mohtasham Kia Y, Cannavo A, Bahiraie P, Alilou S, Saeedian B, Babajani N, et al. Insights into the role of galectin-3 as a diagnostic and prognostic biomarker of atrial fibrillation. *Dis Markers*. 2023;2023:2097012. doi: 10.1155/2023/2097012.
21. Simu GR, Tomoaia R, Rosu RO, Gusetu G, Puiu M, Cismaru G, et al. Galectin-3, Inflammation, and the Risk of Atrial High-Rate Episodes in Patients with Dual Chamber Pacemakers. *Int J Mol Sci*. 2023;24(9):7710. doi: 10.3390/ijms24097710.
22. Felker GM, Fiuzat M, Shaw LK, Clare R, Whellan DJ, Bettari L, et al. Galectin-3 in ambulatory patients with heart failure: results from the HF-ACTION study. *Circ Heart Fail*. 2012;5(1):72-78. doi: 10.1161/CIRCHEARTFAILURE.111.963637.