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Predictive value of SF-12 in assessing quality of life and clinical outcomes after permanent pacemaker implantation: A comparative study between physiological and conventional pacing techniques

Valor predictivo del SF-12 en la evaluación de la calidad de vida y los resultados clínicos tras la implantación de un marcapasos permanente: un estudio comparativo entre técnicas de estimulación fisiológica y convencional

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SUMMARY

Background: *Permanent pacemaker (PPM) implantation is a widely utilized treatment for patients with bradyarrhythmia. While conventional pacing is effective, it may result in electrical desynchrony and impaired cardiac function. In contrast, physiological pacing aims to preserve the heart's native conduction pathways, potentially offering improved clinical outcomes. Assessing quality of life (QoL) is essential not only for monitoring patient well-being but also for identifying individuals at increased risk of adverse events. The Short Form-12 (SF-12) questionnaire offers a concise, validated tool for assessing physical and mental health domains, and may serve as an early predictor of clinical outcomes. This study aimed to evaluate the predictive value of SF-12 in assessing QoL and clinical outcomes in patients undergoing PPM implantation, comparing conventional versus physiological pacing techniques.* **Methods:** *A total of 47 patients were enrolled and categorized into two groups: conventional pacing (n = 14) and physiological pacing (n = 33). SF-12 scores, including the Physical Component Summary (PCS-12) and Mental Component Summary (MCS-12), were analyzed in conjunction with clinical outcomes, such as major adverse cardiac events (MACE), rehospitalization, and mortality. Receiver operating characteristic (ROC) curve analysis was used to assess the predictive performance of SF-12 scores.* **Results:** *Post-implantation, PCS-12 scores improved significantly in both groups, with greater improvement observed in the physiological pacing group (p = 0.035). MCS-12 scores also improved; however, intergroup differences were not statistically significant. No significant differences were found between the two groups in terms of MACE, rehospitalization, or mortality. ROC analysis indicated*

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moderate predictive value for PCS-12 (AUC = 0.642), while MCS-12 showed limited discriminative ability. **Conclusions:** *Physiological pacing was associated with superior improvement in physical quality of life. Although SF-12, particularly PCS-12, shows promise as a predictive tool for clinical outcomes, larger studies are needed to validate its prognostic utility.*

Keywords: *Physiological pacing, conventional pacing, quality of life, SF-12, major adverse cardiac events (MACE).*

RESUMEN

Antecedentes: *La implantación de marcapasos permanente (MPP) es un tratamiento ampliamente utilizado en pacientes con bradiarritmias. Aunque la estimulación convencional es eficaz, puede provocar disincronía eléctrica y deterioro de la función cardíaca. En contraste, la estimulación fisiológica busca preservar las vías de conducción nativas del corazón, lo que podría traducirse en mejores resultados clínicos. La evaluación de la calidad de vida (CdV) es fundamental no solo para monitorizar el bienestar del paciente, sino también para identificar a aquellos con mayor riesgo de eventos adversos. El cuestionario Short Form-12 (SF-12) es una herramienta validada, rápida y eficaz para valorar los dominios físico y mental de la salud, y podría actuar como predictor temprano de los desenlaces clínicos. El objetivo de este estudio fue evaluar el valor predictivo del SF-12 en la determinación de la CdV y los resultados clínicos en pacientes sometidos a implantación de MPP, comparando técnicas de estimulación convencional y fisiológica.* **Métodos:** *Se incluyeron 47 pacientes, divididos en dos grupos: estimulación convencional (n = 14) y estimulación fisiológica (n = 33). Se analizaron las puntuaciones del SF-12, incluyendo el componente físico (PCS-12) y el componente mental (MCS-12), junto con los desenlaces clínicos como eventos cardiovasculares adversos mayores (MACE), rehospitalización y mortalidad. Se utilizó el análisis de curvas ROC para evaluar la capacidad predictiva de las puntuaciones del SF-12.* **Resultados:** *Tras la implantación, las puntuaciones PCS-12 mejoraron significativamente en ambos grupos, con una mejoría mayor en el grupo de estimulación fisiológica (p = 0,035). Las puntuaciones MCS-12 también mejoraron, aunque sin diferencias significativas entre grupos. No se observaron diferencias estadísticamente significativas en cuanto a MACE, rehospitalización o mortalidad. El análisis ROC mostró una capacidad predictiva moderada para el PCS-12 (AUC = 0,642), mientras que el MCS-12 presentó un valor predictivo limitado.* **Conclusiones:** *La estimulación fisiológica se asoció con una mejora superior en la calidad de vida física. Aunque el SF-12, especialmente el PCS-12, muestra potencial como herramienta predictiva de desenlaces clínicos, se requieren estudios con muestras más amplias para validar su utilidad pronóstica.*

Palabras clave: *Estimulación fisiológica, estimulación convencional, calidad de vida, SF-12, eventos cardiovasculares adversos mayores (MACE).*

INTRODUCTION

A permanent pacemaker (PPM) plays a vital role in managing bradyarrhythmia, restoring normal heart rhythm, and improving patients' quality of life (1). Conventional right ventricular pacing (RVP), while effective, often leads to electrical desynchrony that may impair long-term cardiac function (2). In contrast, physiological pacing techniques, such as His bundle pacing (HBP) and left bundle branch area pacing (LBBaP), aim to preserve the heart's natural conduction system, offering potential benefits in cardiac synchrony and outcomes (3,4).

Patients with conduction disturbances often report not only physical symptoms, but also emotional distress, anxiety, and a diminished ability to carry out daily activities (5,6). These impairments can persist even after rhythm correction, especially during the early adjustment period following pacemaker implantation. Measuring HRQoL shortly after implantation, therefore, provides a broader view of patient recovery and may help guide timely interventions such as rehabilitation, psychological support, or pacing optimization.

The Short Form-12 Health Survey (SF-12) questionnaire, a condensed version of the SF-36, is widely used to assess health-related quality of life (HRQoL) through its physical component score (PCS-12) and mental component score (MCS-12) (7). This study investigates the utility of SF-12 in predicting clinical outcomes, including rehospitalization and major adverse cardiac events (MACE), following PPM implantation. It compares QoL outcomes between conventional and physiological pacing techniques.

METHODS

This observational, single-center study included 47 patients undergoing PPM implantation, divided into two groups: conventional pacing (n = 14) and physiological pacing (n = 33). The inclusion criteria for this study are patients aged ≥ 18 years old who underwent PPM implantation. The exclusion criteria are patients with autoimmune disease, severe infection, neoplasm, and mental disorder. Demographic and baseline clinical data were collected, including blood pressure, ejection fraction (EF), and comorbidities.

The SF-12 questionnaire was administered before and after implantation to assess HRQoL. Primary outcomes included changes in PCS-12 and MCS-12 scores. Secondary outcomes included length of hospital stay, mortality, rehospitalization, and MACE over a 6-month follow-up. Statistical analyses included the Chi-Square test, Fisher's exact test, Mann-Whitney U test, Wilcoxon test, and ROC curve analysis to evaluate predictive performance.

RESULTS

A total of 47 patients were enrolled in the study and divided into two groups: the conventional pacing group (n = 14) and the physiological pacing group (n = 33). Baseline demographic and clinical characteristics were comparable between groups, indicating homogeneity.

Demographic and Clinical Characteristics

No statistically significant differences were observed in age (p = 0.973), sex (p = 0.973), education level (p = 0.614), or income (p = 0.742) (Table 1). Clinical parameters, including systolic and diastolic blood pressure, ejection fraction, tricuspid annular plane systolic excursion (TAPSE), heart rate, and body mass index (BMI), also did not differ significantly (all p > 0.05). The distribution of comorbid conditions, including acute coronary syndrome (ACS), hypertension, and diabetes mellitus, was similar between groups (Table 2).

Table 1. Baseline Demographic Characteristics of Subjects in the Conventional and Physiological Pacing Groups

Characteristics	Conventional (n = 14)	Physiological (n = 33)	Total (N = 47)	p value
Age (years)				0.973[a]
≤ 60, n (%)	6 (42.9)	16 (48.5)	22 (46.8)	
> 60, n (%)	8 (57.1)	17 (51.5)	25 (53.2)	
Sex				0.973[a]
Male, n (%)	8 (57.1)	17 (51.5)	25 (53.2)	
Female, n (%)	6 (42.9)	16 (48.5)	22 (46.8)	
Education				0.614[b]
Primary, n (%)	3 (21.4)	10 (30.3)	13 (27.7)	
Secondary, n (%)	8 (57.1)	14 (42.4)	22 (46.8)	
Tertiary, n (%)	2 (14.3)	8 (24.2)	10 (21.3)	
No Formal Education, n (%)	1 (3.0)	1 (7.1)	2 (4.3)	
Monthly income				0.742[b]
≤ 3 million (IDR), n (%)	9 (64.3)	23 (69.7)	32 (68.1)	
> 3 million (IDR), n (%)	5 (35.7)	10 (30.3)	15 (31.9)	

[a]Chi Square, [b]Fisher Exact test. IDR: Indonesian Rupiah.

Table 2. Baseline Clinical Characteristics of Subjects in the Conventional and Physiological Pacing Groups.

Characteristics	Conventional (n = 14)	Physiological (n = 33)	Total (N = 47)	p value
Systolic BP (mmHg)	135.4 ± 25.3	131.0 ± 21.3	132 ± 22.4	0.572[a]
Diastolic BP (mmHg)	78.3 ± 12.9	73.4 ± 13.6	74.8 ± 13.4	0.252[a]
Heart Rate (bpm)	60.7 ± 15.2	52.2 ± 19.8	54.8 ± 18.8	0.067[b]
BMI (kg/m²)	22.9 ± 3.3	23.8 ± 4.2	23.6 ± 3.9	0.843[b]
LV Ejection Fraction (%)	49.6 ± 9.3	52.6 ± 9.2	51.7 ± 9.2	0.322[b]
< 40 %, n (%)	2 (14.3)	3 (9.1)	5 (10.61)	0.627[c]
≥ 40 %, n (%)	12 (85.7)	30 (90.9)	42 (89.4)	
TAPSE (cm)	1.9 ± 0.2	2.0 ± 0.3	1.9 ± 0.2	0.981[b]
History of ACS				0.627[c]
Yes, n (%)	2 (14.3)	3 (9.1)	5 (10.6)	
No, n (%)	12 (85.7)	30 (90.9)	42 (89.4)	
Hypertension				1.000[d]
Yes, n (%)	8 (57.1)	19 (57.6)	27 (57.4)	
No, n (%)	6 (42.9)	14 (42.4)	20 (42.6)	
Diabetes Mellitus				
Yes, n (%)	1 (7.1)	7 (21.2)	8 (17.0)	0.405[c]
No, n (%)	13 (92.9)	26 (78.8)	39 (83.9)	

[a]Independent T test, [b]Mann-Whitney U test, [c]Fisher Exact test, [d]Chi Square. BMI: Body Mass Index; TAPSE: Tricuspid Annular Plane Systolic Excursion; ACS: Acute Coronary Syndrome. BP: Blood pressure. LV: Left Ventricle.

Quality of Life Before and After PPM Implantation

Prior to implantation, both PCS-12 and MCS-12 scores showed no significant difference between groups (p = 0.081 and p = 0.159, respectively) (Table 3). Post-implantation, the PCS-12 score improved significantly in both groups; however, the physiological group demonstrated a greater increase (median 49.9 vs. 41.3, p = 0.035), indicating a statistically significant difference in physical QoL improvement. MCS-12 scores improved in both groups as well; however, the intergroup comparison did not show a significant difference (p = 0.599) (Table 4).

Intra-group analysis revealed a significant improvement in both PCS-12 and MCS-12 scores after pacemaker implantation for both groups (p < 0.05) (Table 5, Figure 1).

Table 3. Comparison of QoL Scores (SF-12) before Permanent Pacemaker Implantation between the Conventional and Physiological Groups.

Component of SF-12	Conventional (n = 14)	Physiological (n = 33)	Total (N = 47)	p value
PCS-12	36.5 (24.7–48.2)	42.1 (24.6–45.4)	40.8 (24.6–48.2)	0.081
MCS-12	35.4 (28.6–49.0)	41.8 (29.8–48.2)	39.1 (28.6–49)	0.159

Mann-Whitney U test. PCS: Physical Component Summary; MCS: Mental Component Summary.

Table 4. Comparison of QoL Scores (SF-12) after Permanent Pacemaker Implantation between the Conventional and Physiological Groups.

Component of SF-12	Conventional (n = 14)	Physiological (n = 33)	Total (N = 47)	p value
PCS-12	41.3 (36.5–54.8)	49.9 (37.7–55.2)	48.1 (36.5–55.2)	0.035*
MCS-12	48.5 (42.4–54.5)	49.2 (40.3–56.4)	49.2 (40.3–56.4)	0.599

Mann-Whitney U test, *p < 0.05. PCS: Physical Component Summary; MCS: Mental Component Summary.

Table 5. Intra-Group Comparison of QoL Scores (SF-12) Before and After Permanent Pacemaker Implantation

Component of SF-12	Before PPM	After PPM	Total (N = 47)
PCS-12 Conventional (n=14)	36.5 (24.7-48.2)	41.3 (36.5-54.8)	0.009
PCS-12 Physiological (n=33)	42.1 (24.6-45.4)	49.9 (37.7-55.2)	p < 0.0001
MCS-12 Conventional (n=14)	35.4 (28.6-49.0)	48.5 (42.4-54.5)	0.001
MCS-12 Physiological (n=33)	41.8 (29.8-48.2)	49.2 (40.3-56.4)	0.0001

Wilcoxon Signed-Rank test, *p < 0.05. PCS: Physical Component Summary; MCS: Mental Component Summary.

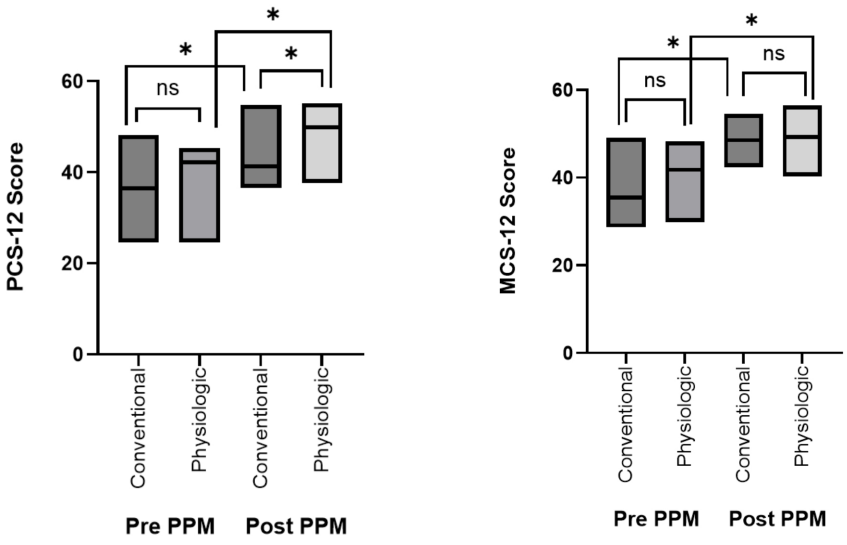

Figure 1. Comparison of PCS-12 and MCS-12 scores before and after PPM implantation using conventional and physiological pacing. *p < 0.05.

Clinical Outcomes

During the 6-month follow-up, mortality occurred only in the physiological group (6.1 %), while the conventional group recorded no deaths. Rehospitalization and MACE occurred in 30.3 % of the physiological group and 14.3 % of the conventional group. However, these differences were not statistically significant (p = 0.302 for both). The mean length of hospital stay was similar between groups (5.6 vs. 5.7 days, p = 0.432) (Table 6).

Table 6. Comparison of Clinical Outcomes Between the Conventional and Physiological Pacing Groups

Clinical Outcomes	Conventional (n = 14)	Physiological (n = 33)	Total (N = 47)	p value
Death, n (%)	0 (0.0)	2 (6.1)	2 (4.3)	1.000[a]
Rehospitalization, n (%)	2 (14.3)	10 (30.3)	12 (25.5)	0.302[a]
MACE, n (%)	2 (14.3)	10 (30.3)	12 (25.5)	0.302[a]
Treatment Duration (days)	5.7 ± 4.5	5.6 ± 2.3	5.6 ± 3.0	0.432[b]

[a]Fisher Exact test, [b]Mann Whitney. MACE: Major Adverse Cardiac Event.

Predictive Analysis of SF-12 for MACE

Receiver operating characteristic (ROC) curve analysis showed that PCS-12 had a moderate discriminative ability for predicting MACE (AUC = 0.642, 95 % CI: 0.461–0.822, p = 0.147), while MCS-12 had poor discriminative capacity (AUC = 0.455, 95 % CI: 0.270–0.640, p = 0.643) (Figure 2, Table 7). The optimal PCS-12 cut-off value was 41.25 (sensitivity, 58.3 %; specificity, 57.1 %), and for the MCS-12, it was 39.9 (sensitivity, 41.7 %; specificity, 48.6 %) (Figure 3, Table 8).

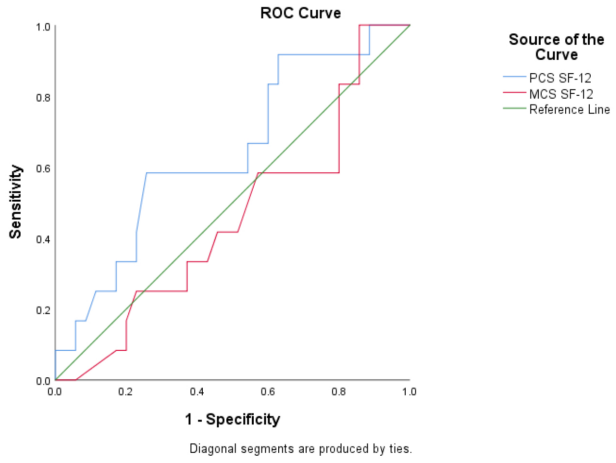

Figure 2. ROC Curve of PCS-12 and MCS-12 scores in predicting major adverse cardiac events (MACE).

Table 7. Area Under the Curve (AUC) of SF-12 as a Predictor of Major Adverse Cardiac Events (MACE).

Component of SF-12	AUC	95 % CI (upper-lower)	p value
PCS-12	0.642	0.461–0.822	0.147
MCS-12	0.455	0.270–0.640	0.643

AUC: Area Under the Curve; PCS: Physical Component Summary; MCS: Mental Component Summary.

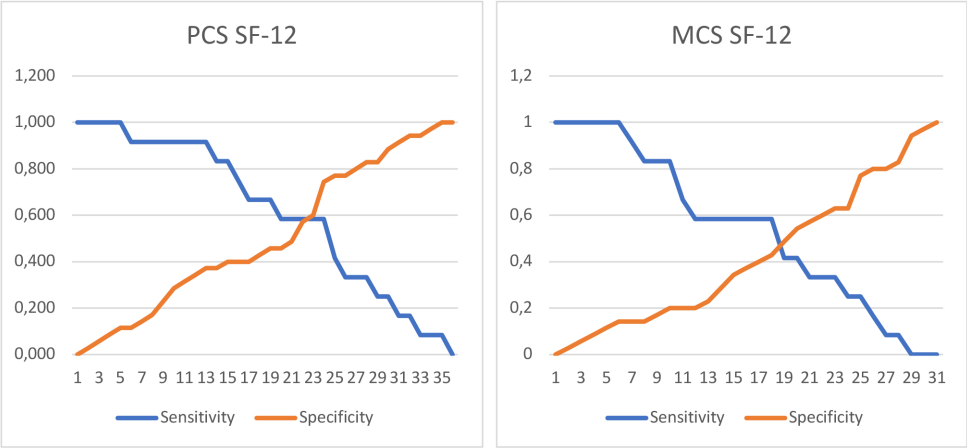

Figure 3. Cut-Off Value Graph for PCS-12 and MCS-12 in Predicting Major Adverse Cardiac Events (MACE).

Table 8. Cut-Off Points, Sensitivity, and Specificity of SF-12 in Predicting Major Adverse Cardiac Events (MACE).

Component of SF-12	Cut-off Point	Sensitivity (%)	Specificity (%)
PCS-12	41.25	58.3	57.1
MCS-12	39.9	41.7	48.6

PCS: Physical Component Summary; MCS: Mental Component Summary.

DISCUSSION

Post-implantation SF-12 scores showed significant improvement in both groups, highlighting the role of PPMs in enhancing patients' perceived quality of life. However, patients receiving physiological pacing experienced significantly greater improvements in physical functioning. This finding aligns with prior research suggesting that physiological pacing better preserves ventricular synchrony, resulting in improved cardiac output and functional capacity (1,8,9).

The mental health component (MCS-12) also improved after implantation, but the difference between groups was not statistically significant. This may reflect the multifactorial nature of psychological recovery, which can be influenced by baseline mental health status, social support systems, and the emotional adjustment to living

with an implanted device—factors not directly addressed by pacing technique alone (10).

No statistically significant differences were observed in mortality, rehospitalization, or MACE rates between the two groups. The relatively low incidence of adverse events and short follow-up period likely contributed to the lack of significance. Prior studies with longer follow-up durations have shown a reduced incidence of heart failure hospitalizations and mortality in patients with physiological pacing (11). Thus, the findings from this study may reflect early-stage trends that require longer-term observation to achieve statistical power.

The PCS-12 component demonstrated a moderate but non-statistically significant ability to predict MACE events, suggesting its potential utility as a simple screening tool. The low performance of MCS-12 implies that psychological health alone may not be a sufficient predictor of clinical outcomes, at least in the early post-implantation period. These findings are consistent with the existing literature, which indicates that physical health is more closely tied to cardiovascular prognosis (13,14). PCS-12, which assesses physical aspects such as bodily function, limitations due to physical problems, and bodily pain, may better reflect clinical conditions directly related to the occurrence of MACE. On the other hand, although mental health status is also known to contribute to cardiovascular prognosis through mechanisms such as chronic stress and depression (15,16). The MCS-12 score in this study did not demonstrate good predictive ability. Nevertheless, the simplicity and speed of administering the SF-12 questionnaire make it a promising tool, not only for tracking recovery but also for flagging patients at higher risk (15). Integrating this kind of screening into early post-implantation care could lead to more proactive management strategies, particularly in resource-limited settings.

Given the positive impact on physical QoL, physiological pacing may be considered the preferred technique, particularly in patients with higher physical demands or risk of pacing-induced cardiomyopathy. However, due to the lack of significant differences in clinical endpoints, clinical decision-making should still consider patient-specific factors, operator expertise, and institutional resources. In clinical environments with limited access to advanced pacing tools, conventional pacing remains a valuable option, providing substantial benefits.

Study Limitations

This study has several limitations, including its small sample size, short follow-up duration, and single-center design. Moreover, the study relied solely on self-reported QoL measures without integrating objective biomarker data, which may have strengthened the predictive analysis.

CONCLUSIONS

Physiological pacing offers greater benefits in improving the physical quality of life compared to conventional pacing. While no significant differences were observed in short-term clinical outcomes, SF-12, particularly the PCS-12 score, shows potential as a predictive tool for adverse cardiac events. The routine integration of SF-12 in clinical practice could aid in monitoring recovery and risk stratification, although further research is needed to confirm these findings.

Conflict of interest

None declared.

Funding

None declared.

Authors' contributions

DNSH, MA, and AQ conceived the idea and formulated the research questions. DNSH performed data collection, responsible for the initial data analysis. DNSH and AQ drafted the initial manuscript. AQ prepared the final version of the manuscript for submission and made a proofread. MA, AHN, AAZ, and PK reviewed the manuscript and provided further revisions. All authors read and approved the final manuscript.

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