

Appropriate application of diagnostics for identifying patients in need of pacemaker therapy

Mazen Tawfik^{1*}, Mohamed Mousa¹, Apichai Pokawattana²,
Surachat Jaroonpipatkul², and Kieu Ngoc Dung³

¹Cardiology Department, Faculty of Medicine, Ain Shams University Hospital, Ain Shams University, Abbasia Street, Abbasia District, Cairo 11517, Egypt; ²Division of Cardiology, Rajavithi Hospital, College of Medicine, Rangsit University, Bangkok, Thailand; and ³Department of Cardiology, Division of Electrophysiology, Cho Ray Heart Center, Ho Chi Minh City, Vietnam

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Pacemaker therapy is the cornerstone in treatment of bradycardia and conduction disorders. Several diagnostic tools are utilized to diagnose and guide the physicians for appropriate management and accordingly proper utilization of pacemaker therapy. The current article is discussing the different diagnostics used for appropriate evaluation and diagnosis of bradyarrhythmias and the suggested solutions to improve bradycardia diagnosis and pacemaker therapy utilization in underpenetrated areas.

Introduction

Pacemaker therapy is the most important management for cardiac conduction disorders and bradyarrhythmia, improving quality of life and increasing life expectancy for patients.¹ However, identifying the right candidates for pacemaker implantation is a crucial part for maximizing the benefits of this intervention. Recent advancements in diagnostic cardiology have strengthened the identification and evaluation of patients with underlying conduction abnormalities. There are many regions of developing countries that lack access to quality medical treatment. These areas still lack access to cardiac pacing for the treatment of bradyarrhythmias or tachyarrhythmias, as well as medical personnel who can diagnose, recommend, or implant cardiac pacing devices.

This article explores the burden of bradycardia in developing countries and the appropriate application of diagnosis to identify patients in need of pacemaker therapy, highlighting key considerations and recent developments. Also, methods to improve training of physicians imply the

role of governments, non-governmental organizations, industry, and medical societies in expanding bradycardia therapy access.

Magnitude of the problem (burden of bradycardia and access to bradycardia therapy in underserved countries)

In sub-Saharan Africa, 5 of the 34 nations (15%) do not have even one qualified cardiologist to offer basic cardiac care. More than half of the Sub Saharian Area nations lack a cardiac catheterization laboratory, and a third lack even a single pacemaker centre.²

The standard of care for cardiovascular diseases differs significantly between industrialized and low- and middle-income nations. Cardiac arrhythmia may be the most underappreciated field of cardiology due to the high expense of diagnostic and therapeutic procedures in electrophysiology.

In developing countries, there is a large disparity in the availability of cardiac arrhythmia diagnostic tools. Outside of the big cities, it is difficult to obtain medicines, electrocardiography (ECG), echocardiography, ambulatory ECG monitoring, exercise stress testing, and head-up tilt testing.

*Corresponding author. Tel: +201221004202, Fax: +20224820416,
Email: mazentawfik@gmail.com

Table 1 Diagnostic approach for identifying patients in need of pacemaker therapy

Approach	Methods
Non-invasive diagnostic approach	<ol style="list-style-type: none"> 1. History and physical examination 2. Electrocardiography (ECG): short and long duration 3. Cardiac imaging (e.g. echocardiography, CT-scan, and CMR) 4. Blood test (finding cause and preparing case) 5. Tilt testing 6. Other non-invasive testing (e.g. sleep test and carotid sinus massage)
Invasive diagnostic approach	<ol style="list-style-type: none"> 1. Implantable loop recorder 2. Electrophysiologic study

CMR, cardiac magnetic resonance; CT-scan, computed tomography.

Almost one-third of African countries do not implant pacemakers due to a lack of diagnostic equipment, and hundreds of millions of people lack sufficient access to therapy for bradycardia, particularly for heart block.³

Diagnosis of cardiac conduction disorder and bradyarrhythmia

The initial evaluation of patient who may need pacemaker therapy starts with precise history taking and physical examination to evaluate cause of conditions (e.g. side effect of medication, metabolic derangement, and infection) and the complications that occur after the bradycardia (e.g. head injury, heart failure, and angina) (Table 1). Not only the history and physical examination by medical personnel are important but also the data from personal equipment (such as smart watches, pulse oximetry, and home blood pressure monitoring) are valuable.

Non-invasive diagnostic approach

(1) History and physical examination

- a. Frequency, severity, and duration are the focus of history taking. Circumstances of situation that symptom occurred are also important, for example, physical activity, changing position, and trigger of episode. In young patients, family history needs to be explored.
- b. Some cardiac disease could be revealed during physical examination, and physicians should be careful to evaluate the complication that may occur during bradycardia (e.g. bone fracture, head injury, signs, and symptoms of heart failure).
- c. Currently available heart rate monitoring smartwatches in the market are capable to detect cardiac arrhythmia. There were two types of smartwatches including heart rate counting-only device [photoplethysmography (PPG)] and ECG-recording capable device. For the heart rate

counting-only, the accuracy for detection of arrhythmia is certainly high and reliable (positive predictive value 85% and negative predictive value 100%).⁴ On the other hand, the ECG-recording capable device is that same as single-lead ECG, but it needs to be activated for recording.

(2) Electrocardiography

- a. Electrocardiography is the definite tool to evaluate this condition. But in certain conditions (including intermittent symptoms, unpredictable symptoms, and event-trigger episode), the standard 12-lead ECG may not be helpful.
- b. Long-duration ECG-recording devices are also available (e.g. 24-72 h ambulatory ECG monitoring, event recorder, and external ECG monitoring patch). This will be appropriate for patients with intermittent symptoms.
- c. Recording of ECG during exercise will be helpful in case of exercise-induced symptoms. It is reasonable for both arrhythmic diagnostic purpose and coronary artery disease evaluation.

(3) Cardiac imaging

- a. Evaluation with cardiac imaging [e.g. echocardiography, cardiovascular magnetic resonance, and computed tomography (CT)] became an essential approach for patients suspected of bradyarrhythmia. Some cardiac conditions (such as aortic stenosis, amyloidosis, and cardiomyopathy) may be found during investigation and leading us to proper treatment for certain conditions. Cardiac imaging is valuable to choose the appropriate device for patients. In case of cardiomyopathy with low ejection fraction, we will consider cardiac resynchronization therapy rather than permanent pacemaker in patients which expected high ventricular pacing rate.

(4) Blood test

- a. Laboratory examinations are an important part for finding cause of arrhythmia and preparing for procedure. To find the cause, treatable conditions should be considered (e.g. thyroid disease, potassium level, and calcium level), which depend on suspected conditions. To prepare the case, complete blood count and basic coagulation should be checked.

(5) Tilt testing

- a. It would be an appropriate test for patients with suspected reflex syncope. Reproducible symptoms with cardio-inhibitory response (asystolic pause or marked bradycardia) are indication for pacemaker therapy.

(6) Other non-invasive testing

- a. Further non-invasive evaluation, it should depend on clinical situation. Sleep study should be done in case of suspected obstructive sleep apnoea. Carotid sinus massage should be considered in case of suspected carotid hypersensitivity.

Invasive diagnostic approach

- (1) Implantable cardiac rhythm monitoring device (loop recorder)

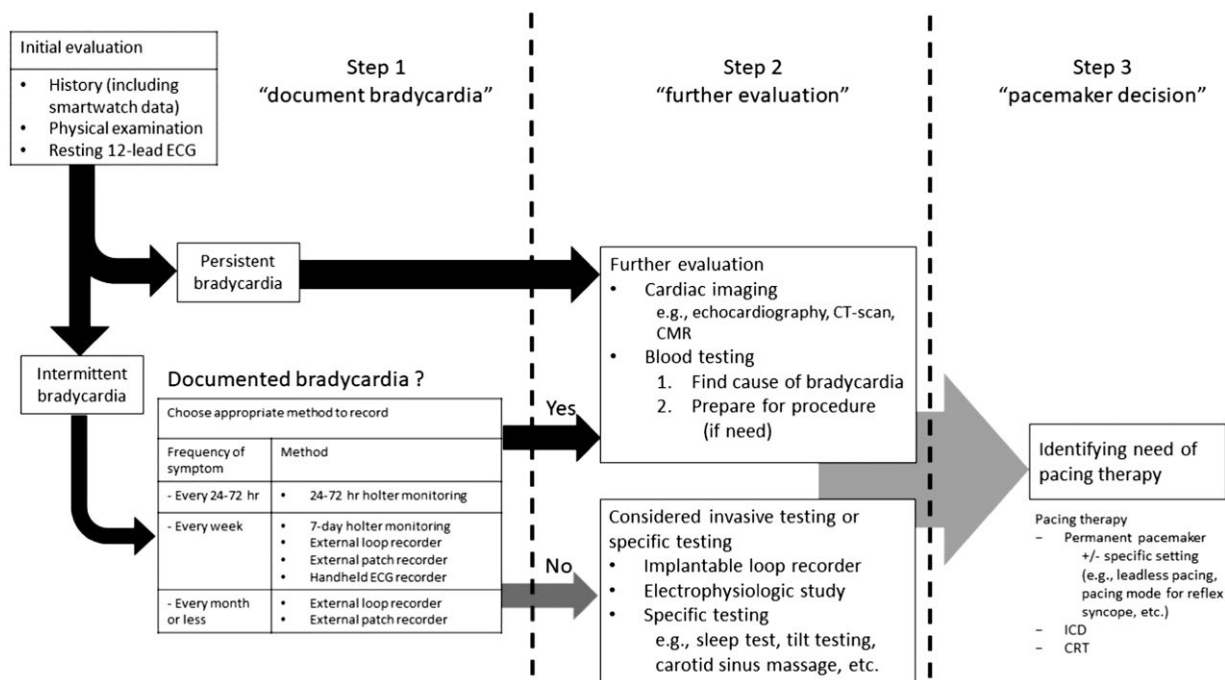


Figure 1 Central illustration of appropriate application of diagnostics for identifying patients in need of pacemaker therapy. CMR, cardiac magnetic resonance; CRT, cardiac resynchronization therapy; CT-scan, computed tomography; ECG, electrocardiography; ICD, implantable cardioverter defibrillator.

a. In patients with intermittent and unpredictable symptoms, implantable cardiac rhythm monitoring device should be considered. A loop recorder automatically records ECG signal. As compared with currently available smartwatch that needs to be activated for ECG recording, loop recorder will be more appropriate for patient with severe symptom or require very long duration of monitoring (up to 3 years).⁵

(2) Electrophysiologic study

a. Due to advancement in non-invasive cardiac diagnostic technology, role of invasive electrophysiologic study is lessened. According to the current ESC guideline for cardiac pacing 2021, electrophysiologic study should be considered in case of syncope with bifascicular block or sinus bradycardia, which is unexplained by non-invasive testing.⁶

b. Diagnosis application in patients who may need pacemaker therapy can be done with both invasive and non-invasive testing. To choose the appropriate method, it will depend on the clinical circumstance of patients.

Appropriate diagnostic evaluation of patients with suspected or documented bradycardia

Diagnostic evaluation of patients depends on clinical presentation and clinical circumstances. Patients with continuing bradycardia will require fewer tests for treatment plan. On the other hand, patients with discontinuing or unpredictable bradycardia may need to document bradycardia before choosing the proper plan. In order to choose the appropriate test, we categorize patients into two groups, including patients with persistent bradycardia and patients with intermittent bradycardia^{5,6} (Figure 1).

(1) Patients with persistent bradycardia

a. Bradycardia, defined as a resting heart rate below 60 b.p.m., poses challenges in evaluation and management. Persistent bradycardia indicates a sustained slow heart rate over an extended period, often associated with underlying cardiac conditions.^{9,10} Diagnostic tests such as physical examination, ECG, and echocardiography aid in accurate diagnosis and appropriate management strategies. Specific laboratory tests, including thyroid function tests, Lyme titre, digitalis level, and electrolyte measurements, help diagnose and treat potential reversible underlying causes contributing to bradycardia. Additionally, a 12-lead ECG provides valuable information about rhythm, conduction disturbances, and structural heart abnormalities.⁶

(2) Patients with intermittent bradycardia

a. Intermittent bradycardia refers to episodes of slower heart rates occurring intermittently. Ambulatory ECG monitoring, such as Holter monitoring, external loop recorders, or patch recorders, allows for the detection and analysis of rhythm disturbances associated with symptoms.¹¹ These are various types of ambulatory ECG for monitoring bradycardia, ranging from daily monitoring to less frequent intervals. Monitoring techniques include 24-h Holter ECG or in-hospital telemetric monitoring, performed every 48-72 h, as well as 24-48-72 h Holter ECG recordings. Weekly monitoring options include 7-day Holter ECG, external loop recorders, and external patch recorders. For longer intervals, monthly monitoring can be achieved using external loop recorders, external patch recorders, or handheld ECG recorders. In cases where bradycardia events

occur infrequently, an implantable loop recorder (ILR) may be utilized, with recordings of less than one per month. These various monitoring methods allow healthcare providers to capture and analyse the patient's heart rhythm over different durations, helping to identify episodes of bradycardia and their characteristics.

- b. Exercise testing also plays a vital role in evaluating patients with intermittent bradycardia, especially those experiencing symptoms during or after physical exertion. It helps observe heart rate response and identify abnormalities associated with bradycardia. Exercise testing also aids in assessing chronotropic incompetence and exposing underlying infra-nodal blocks in patients with intraventricular conduction disease or atrioventricular block of unknown level.^{6-8,11,12}
- c. Cardiac imaging is recommended for patients with suspected or documented symptomatic bradycardia to assess structural heart disease, left ventricular systolic function, and potential causes of conduction disturbances. Multimodality imaging techniques such as cardiac magnetic resonance (CMR), CT, or positron emission tomography (PET) should be considered, particularly for myocardial tissue characterization in specific pathologies associated with conduction abnormalities requiring pacemaker implantation. These imaging modalities are particularly valuable for patients under 60 years of age.⁶

Suggested solutions to improve bradycardia diagnosis in underdeveloped areas

There are many regions of developing countries that lack access to quality medical treatment. These areas still lack access to cardiac pacing for the treatment of bradyarrhythmias or tachyarrhythmias, as well as medical personnel who can diagnose, recommend, or implant cardiac pacing devices.

(1) Infrastructure

With effective education programmes and campaigns, the availability of primary care and awareness about referring patients who require pacemakers or cardiac devices to tertiary care facilities should be promoted.

Electrocardiography, Holter, event recorders, stress ECG, and Echo should be available in most sectorial hospitals and 2ry care healthcare facilities.

The appropriate diagnostic tests and procedures will depend on the patient's symptoms, medical history, and the suspected underlying condition. A cardiologist will determine which tests are necessary to accurately diagnose and treat the patient.

(2) Education

Developing countries often have untapped potential in terms of natural resources, human capital, and geographical advantages. To utilize these resources effectively, it is important to focus on several key areas, of

which education and training are one of the most important things that developing countries can invest in. Through education, people can gain the skills and knowledge they need to improve their living standards and their health awareness.¹³

(3) Finance

As there is usually a financial problem related to implication of diagnostic screening, we suggest using pulse oximetry to screen for bradycardia then refer patients to the dedicated Electrophysiology (EP) clinics to further investigate for the need of pacing.

As a simple, non-expensive test, pulse oximeters can be used to detect low heart rate (HR) < 50 b.p.m.; however, some arrhythmias like ventricular bigeminy can be falsely diagnosed as bradycardia, after referral to a well-trained cardiologist who can differentiate between both types of arrhythmias.

Despite pulse oximeters are very prone to motion artefacts, newly developed instruments have lower false positive values.¹⁴

We suggest using pulse oximeters in screening old age patients > 60 years for bradycardia < 50 b.p.m. with an additional short questionnaire about low cardiac symptoms (dizziness, syncope, falls, and blackouts) and then escalate to 12-lead ECG or 24 h Holter monitoring after clinical assessment to exclude 2ry causes and correlate with patient's symptoms.

This simple diagnostic tool can be incorporated to national screening campaigns, and here the role of governments and non-governmental organizations will be implemented to sponsor these campaigns and medical follow-up and treatment of patients who are in need.

(4) Other practical recommendations

In developing countries, appropriate application of diagnostics for identifying patients in need of pacemaker therapy should consider the following factors:

Availability of diagnostic tests: Developing countries may have limited access to diagnostic tests such as ECG machines and echocardiography, which are important tests for pacemaker candidacy assessment. Therefore, it is important to consider diagnostic tests that are affordable, readily available, and can be performed by trained healthcare providers.

Clinical presentation: The presenting symptoms of a patient should be considered when deciding on pacemaker candidacy. Common symptoms of pacemaker indications include syncope, dizziness, fatigue, chest pain, breathlessness, palpitations, and heart failure. These symptoms can be used as clinical indicators to identify patients who require pacemaker therapy.

Age of the patient: Age is an important factor to consider in identifying patients who require pacemaker therapy. In developing countries, older adult populations are increasing, and they are at a higher risk of developing cardiac conditions that may require pacemaker therapy.

Cost-effectiveness: Pacemaker therapy can be expensive in developing countries. Therefore, it is important to consider the cost-effectiveness of each diagnostic test when deciding on pacemaker candidacy. Tests that are cost-effective, readily available, and can provide accurate results should be preferred.

Conclusion

In summary, appropriate application of diagnostics for identifying patients in need of pacemaker therapy in developing countries should consider the availability of diagnostic tests, clinical presentation, age of the patient, ECG and echocardiography findings, and cost-effectiveness.

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Data availability

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References

1. Barros RT, Carvalho SMR, Silva MAM, Borges JBC. Evaluation of patients' quality of life aspects after cardiac pacemaker implantation. *Rev Bras Cir Cardiovasc* 2014;**29**:37-44.
2. Bonny A, Ngantcha M, Scholtz W, Chin A, Nel G, Anzouan-Kacou JB *et al.* Cardiac arrhythmias in Africa: epidemiology, management challenges, and perspectives. *J Am Coll Cardiol* 2019;**73**:100-109.
3. Talle MA, Bonny A, Scholtz W, Chin A, Nel G, Karaye KM *et al.* Status of cardiac arrhythmia services in Africa in 2018: a PASCAR Sudden Cardiac Death Task Force report. *Cardiovasc J Afr* 2018;**29**:115-121.
4. Scarlet N, Kyle L, Ara D, Hutan A. Diagnostic accuracy of smartwatches for the detection of cardiac arrhythmia: systematic review and meta-analysis. *J Med Internet Res* 2021;**23**:e28974.
5. Alexander C, Antonio F. Smart-watches: a potential challenger to the implantable loop recorder? *Europace* 2016;**18**:791-793.
6. Michael G, Jens CN, Mads BK, Michowitz Yoav, Auricchio Angelo, Barbash Israel Moshe, *et al.* 2021 ESC guidelines on cardiac pacing and cardiac resynchronization therapy. *Eur Heart J* 2021;**42**:3427-3520.
7. Jean-Claude D, Michele B, Régis G. Adenosine hypersensitivity and atrioventricular block. *Herzschrittmacherther Elektrophysiol* 2018;**29**:166-170.
8. Michele B, Auricchio A, Baron-Esquivias G, Bordachar P, Boriani G, Breithardt OA, *et al.* 2013 ESC guidelines on cardiac pacing and cardiac resynchronization therapy: the Task Force on cardiac pacing and resynchronization therapy of the European Society of Cardiology (ESC). developed in collaboration with the European Heart Rhythm Association (EHRA). *Eur Heart J* 2013;**34**:2281-2329.
9. Çinier G, Haseeb S, Bazoukis G, Yeung C, Gül EE. Evaluation and management of asymptomatic bradyarrhythmias. *Curr Cardiol Rev* 2021;**17**:60-67.
10. Nabil ES, José J. Paroxysmal atrioventricular block: are phase 3 and phase 4 block mechanisms or misnomers? *Heart Rhythm* 2009;**6**:1514-1521.
11. Adamec J, Adamec R. *ECG Holter: Guide to Electrocardiographic Interpretation*. New York, NY: Springer; 2008.
12. Mehdi M, Maryam F, Mehdi K. Assessing post-cardiac stress test heart rate recovery and systolic blood pressure recovery in patients suffering from vasovagal syncope. *Electron J Gen Med* 2019;**16**:em118.
13. Morgan JM. New device indications: practice and cost implications in Europe. *Card Electrophysiol Rev* 2003;**7**:49-53.
14. Harris BU, Char DS, Feinstein JA, Verma A, Shiboski SC, Ramamoorthy C. Accuracy of pulse oximeters intended for hypoxemic pediatric patients. *Pediatr Crit Care Med* 2016;**17**:315-320.