# Bradycardia: A Clinician's Guide to Slow Heart Rates

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## Abstract

Bradycardia or suspicion thereof is often encountered in the emergency department. Typically, bradycardia is the result of a serious underlying cardiac condition, electrolyte derangement or pharmaceutical agents, even though it can be a benign physiological response in athlete's heart. Management of symptomatic bradycardia in the emergency setting follow the same principles; removal of contributing factors and initiation of pharmacological therapy to stabilize circulation, starting with atropine. This is followed by beta-adrenergic agonists such as isoprenaline if the effect is not satisfactory. If medications are insufficient in stabilizing the patient, pacemaker therapy is the next step. Transcutaneous pacing can be initiated fast and is not invasive, although it is associated with risk of skin irritation and requires conscious sedation because of the discomfort. A temporary transvenous pacemaker is better tolerated and can be used as a bridge to permanent pacemaker, but risk of dislodgement and cardiac perforation is not negligible. The vast majority of patients with severe bradycardia require a permanent pacemaker, but in some cases the etiology can be treated and the bradycardia cured.

***Keywords:*** *Atrioventricular Block; Bradycardia; Escape Rhythm; Pacemaker; Sick Sinus; Sinoatrial Block; Syncope; Tachy-Brady*

## Abbreviations

AV: Atrioventricular; BPM: Beats Per Minute; LAD: Left Anterior Descending Artery; SA: Sinoatrial; SSS: Sick Sinus Syndrome

## Introduction

In adults a heart rate of 40 to 50 beats per minute (BPM) is considered mild bradycardia, and this is usually when symptoms arise. Bradycardia can be seen in athletes and is then considered physiological [1]. Sick sinus syndrome (SSS) consists of symptomatic bradycardia caused by sinus arrest, sinoatrial (SA) exit block or inability to increase heart rate (chronotropic incompetence).

A resting heart rate of 40 BPM is tolerated without symptoms in people without structural heart disease [2]. Syncope occurs after a short period of asystole and longer periods of circulatory failure leads to reduced flow of oxygenated blood to the brain, which in turn may lead to seizures. In people with coronary artery disease/heart failure this can result in chest pain or even ventricular tachycardia. Most commonly, the symptoms of bradycardia are vague, such as fatigue, dizziness, cognitive impairment, and exercise intolerance. Sometimes symptoms are misinterpreted as depression [1]. Shorter periods of sinus rhythm of 30 - 35 BPM, sinus pauses of less than 2.5 seconds, SA-block, atrioventricular (AV)-block I, and AV nodal escape rhythms may occur during sleep and is often considered normal but individual assessment is required [3].

### Pathophysiology and etiology

SSS and AV-block account for 31% and 46% of pacemaker insertions in Sweden, respectively [4]. Fibrosis of the conduction system is often the underlying cause, but it is important to be aware of specific etiologies (Table 1).

Bradycardia is often present in acute coronary syndrome, especially in inferior wall infarction since the SA and AV nodes typically are both supplied by the right coronary artery [2].

## Sick Sinus Syndrome

The syndrome manifests as sinus bradycardia, SA arrest, SA-block, permanent atrial tachycardia, alternating bradycardia-tachycardia or inadequate pulse reaction to physical activity or stress (chronotropic incompetence) [5]. Out of these sinus bradycardia is the most common, although SA-block (on ECG only grade II can be detected, resulting in intermittent pauses between P-waves the same length as two or more P-P intervals), sinus arrest, and escape rhythms are not uncommon. Tachy-brady syndrome is common in SSS and the incidence increases with age [2]. The mean age of SSS patients is 68 years and there is no gender difference [5]. Sinus node dysfunction is often attributed to idiopathic fibrosis and leads to impaired ability to generate and conduct impulses, though there are a number of other reasons (Table 1).

- Idiopathic fibrosis of the conduction system
- Coronary artery disease
- Antiarrhythmic agents (amiodarone, beta blockers, digoxin, disopyramidol, flecainide, sotalol, propafenone, verapamil)
- Other pharmaceutical agents (donepezil, clonidine, lithium)
- Cardiac interventions (valvular intervention, alcohol septal ablation, myectomy, transplantation, electrophysiological ablation, MAZE)
- Congenital heart disease (levo-transposition of the great arteries, repaired ventricular septal defect, dextro-transposition of the great arteries after surgery)
- Dilated cardiomyopathy (lamin A/C mutation)
- Myocarditis
- Neuromuscular disease (Friedreich's ataxia, Duchenne's, dystrophia myotonica)
- Infiltrative (amyloidosis, sarcoidosis, hemochromatosis, neoplasia)
- Reflex mediated causes (cardioinhibitory syncope, carotid sinus syncope)
- Obstructive sleep apnea syndrome
- High vagal tonus (glossopharyngeal neuralgia)
- Electrolyte derangements (hyperkalemia, hypermagnesemia, hypercalcemia)
- Infectious diseases (borreliosis, bacterial endocarditis)
- Ionizing radiation
- Autoimmune diseases (rheumatoid arthritis, systemic lupus erythematosus, Sjogren's syndrome, scleroderma)
- Increased intracranial pressure (intracerebral hemorrhage, subarachnoid bleeding, hydrocephalus)
- Cervical spinal cord injury
- Endocrinological disorders (hypothyroidism, hypoparathyroidism)
- Hypothermia
- Hypoglycemia
- Jaundice
- Malnutrition (anorexia nervosa)

*Table 1:* Causes of bradycardia. Source: Mann D., et al. Braunwald's Heart Disease: A Textbook of Cardiovascular Medicine [6].

## Atrioventricular block

There are three degrees of AV-block. First-degree AV-block entails that the impulse is delayed between the atria and the ventricles, resulting in prolongation of the PR interval to more than 220 ms. In second-degree AV-block, AV conduction is intermittently blocked; type 1 indicates that the PR interval is progressively lengthened until one QRS complex is lost, while in type 2 the PR interval is constant. If there is no conduction at all through the AV node it is classified as third-degree AV-block, hence the P waves and the QRS complexes are independent of each other (AV dissociation). The ventricular depolarization starts from an accessory pacemaker and depending on where this is located the QRS morphology varies. Junctional rhythm (arising from the AV node) produces a heart rate of 45-50 BPM, rhythms from the bundle of His usually results in a heart rate of between 35 and 40 BPM (both of which result in narrow QRS complexes unless there are further conduction blocks). When the rhythm arises from ventricular myocardium the QRS complexes are wide, and the heart rate is between 20 and 50 BPM (usually 30 - 40).

As is the case with both sinus bradycardia and SSS, AV-block can be caused by ischemia, although age-related degeneration of the His-Purkinje system is the most common cause [2]. Congenital third-degree AV-block is rare, and typically associated with rheumatic disease in the mother, systemic lupus erythematosus being the most common [7].

## Symptoms and examination

Taking a thorough history is important to detect causes that may be reversible and possible to treat without the need of a pacemaker (Table 2). Connecting the symptoms to episodes of arrhythmia is crucial, especially in sinus node dysfunction where the symptoms decide whether pacemaker should be recommended or not. Syncope while lying down or during physical activity can indicate a cardiac cause, including ventricular arrhythmias [8]. If possible, witnesses of a syncope should be questioned, since they may provide additional information. Cardiac syncope characteristically occurs without premonition with fast return of consciousness, except for in the most severe cases where a recovery period resembling the postictal state is sometimes seen. Complete loss of muscle tone during unconsciousness is rare in epilepsy. Movements can occur both during syncope and epileptic seizures, but the duration is seconds in syncope and around a minute in epilepsy. Tongue biting is common in epilepsy, urinary incontinence may occur in both. Postictal confusion is common in epilepsy, uncommon in syncope [9]. Trauma and old age point toward cardiac cause.

- Syncope?
- Horizontal position? During physical exertion? Prodromal symptoms? Tongue bite? Postictal? Trauma? Ask witnesses about seizures and duration.
- Snoring/sleep apnea?
- Angina pectoris?
- Dizziness?
- Dyspnea?
- Tiredness?
- Palpitations?
- Irregular rhythm? Slow or fast?
- Stamina?
- Sudden cardiac death in family members?
- Current medications?

***Table 2:*** *Initial history in suspected bradycardia.*

### Examinations

During an episode of bradycardia, a 12-lead ECG can diagnose the arrhythmia. The computer interpretation can provide guidance but blocked supraventricular escape beats, P waves inside T waves, and third-degree AV-block occurring simultaneously with atrial arrhythmias can be missed. In patients without ongoing bradycardia 24- or 48 hour ECG monitoring, thumb ECG or insertable cardiac monitors can be useful. Electrophysiological examination, invasive and non-invasive, can map the conduction system in better detail but is seldom used in clinical practice. Patients with syncope during or immediately after physical activity should undergo an exercise ECG, where chronotropic incompetence or high-grade AV-block can be detected [1]. Laboratory analyses that should be performed include troponins, thyroid function, liver function, b-type natriuretic peptides, sodium, potassium, and creatinine but sometimes additional tests are required, based on the patient history.

### Treatment

Bradycardia leading to hemodynamic instability, loss of consciousness, ischemic chest pain, acute/worsening heart failure or signs of circulatory shock such as renal failure or mesenteric ischemia must be treated. Atropine is the first drug of choice (although awareness about atropines limited efficacy in several forms of pathological bradycardia is advisable), followed by isoprenaline but dopamine, epinephrine, and glucagon can also be of use (Table 3). Stable patients are monitored, although emergency treatment should be easily available if needed. Oxygen is provided if the patient shows signs of desaturation [10].

| Drug | Indication | Dosage | Comment |
|---|---|---|---|
| Atropine | Initial treatment of bradycardia with hemodynamic instability. | 0,5 mg iv repeated every 3 to 5 minutes if needed, to a maximum of 3 mg. | Risk of ischemia, ventricular arrhythmia and paradoxical bradycardia. |
| Dopamine | When atropine is sinsufficient. | 2 - 10 µg/kg/minute iv, increase dose until desired effect. | Correct hypovolemia. |
| Isoprenaline | When atropine is insufficient. | 2 - 10 µg/minute iv, increase dose until desired effect. | Decreases perfusion in the coronary arteries and increases oxygen demand. Risk for ventricular arrhythmias, especially in high digoxin level. In ischemic patients only use as a bridge to pacing. |
| Epinephrine | When atropine is insufficient. | 2 - 10 µg/min iv, increase dose until desired effect. | Correct hypovolemia. |
| Glucagon | Intoxication with beta blockers or calcium channel blockers. | 2 - 10 mg iv as a bolus dose, then continue infusing 2 - 5 mg/hour. | Risk of hypokalemia and hyperglycemia. |

***Table 3:*** *Drugs used in the treatment of bradycardia. Source: AHA guidelines and Harrigan RA., et al [7,10].*

### Transcutaneous pacemaker

In unstable patients where medication has not been effective transcutaneous pacing is required. Some defibrillators have a pacing function; the pads are placed on the patient's chest, one on the anterior side and one between the scapulae on the posterior side, and the pacing function is activated. To ensure capture (effective pacing) a current of 30 - 50 mA is generally needed. The three ECG cables connected to the defibrillator are needed for adequate sensing of native QRS complexes [11]. The pacing frequency should be set at 70 - 90 BPM in circulatory collapse, but in less dramatic settings 30 - 40 BPM is sufficient; this is also the frequency which is used as back up after syncope caused by a short period of bradycardia. When administering transcutaneous pacing to a patient who is awake, the current should be gradually increased until the pulse is palpable (preferably the femoral pulse) that matches the QRS complexes. An anesthesiologist should be present to administer sedation, since transcutaneous pacing is uncomfortable for the patient. In the event of circulatory collapse

maximal current is used immediately to ensure capture, which can later be decreased if the patient regains consciousness. In cardiac arrest transcutaneous pacing is a complement to cardiopulmonary resuscitation, which is to be performed according to guidelines [12]. As is also the case with electrical cardioversion, there is a risk of local skin lesions [7]. Third-degree AV-block with slow ventricular rate is the most common reason transcutaneous pacing is used, generally as a bridge to temporary or permanent transvenous pacemaker [10].

### Temporary transvenous pacemaker

A temporary transvenous pacemaker provides good control of the rhythm and is better tolerated than transcutaneous pacing [7]. Complete bed rest is required since the electrode is not fixed to the ventricular wall and the risk of dislocation is high. The pacemaker electrode is introduced through the jugular or femoral vein, and fluoroscopic guidance is used to aid in placement of the electrode in the apex of the right ventricle. Anticoagulant and antibiotic prophylaxis according to local routine should be considered, especially since permanent pacemaker is often needed later. Temporary transvenous pacemaker is associated with the risk of serious complications such as perforation or cardiac tamponade [7,13].

Acute coronary syndrome, especially ST-elevation myocardial infarction, can be complicated by high-degree AV-block [8]. An occlusion of the right coronary artery or a dominant circumflex artery may cause ECG signs of inferior infarction (ST elevation in II, aVF and III) and sometimes posterior engagement (reciprocal ST depressions in V1-V4). AV-block II-III (or infra-Hisian block) sometimes develop during anterior wall infarction (ST elevation in V1-V6) secondary to proximal occlusion of the left anterior descending artery (LAD), which is a sign of massive myocardial infarction and poor prognosis [14]. The conduction is generally restored by reperfusion, but in some rare cases temporary transvenous pacemaker is necessary [8]. AV-block that develops as a complication of myocardial infarction generally disappears spontaneously in 2 - 7 days [1]. If it remains, or develops days after the infarction, permanent pacing may be needed.

### Additional treatment

Identifying underlying causes is important in order to provide specific treatment when available. Consulting specialists in, for example, infectious diseases, rheumatology, and neurology is often crucial. A number of exogenous causes can be reversible, and a thorough medication history interview, including dosage, is important. Sometimes specific antidotes are available, as in severe digoxin poisoning, or intoxication with beta blockers or calcium channel blockers in which case glucagon may be used [7]. A change in the pharmacological therapy or prompt withdrawal is often warranted while awaiting pacemaker implantation. Unless there is intoxication dosage, the bradycardia typically reflects severe underlying conduction disease. Therefore, simply withdrawal of drugs triggering bradycardia is not considered enough even with prolonged monitoring, as a life-threatening situation may occur later and is unpredictable, especially in AV-block.

Bradycardia resulting from severe hyperkalemia can be resistant to atropine, so early diagnosis of this electrolyte imbalance is vital [15]. When the potassium level exceeds 7.0 mmol/L or the ECG is affected, it must be corrected immediately (Table 4) [16]. Medications that are known to sometimes cause bradycardia, including eye drops and drugs used in the treatment of dementia (donepezil for example), should be inquired about specifically and discontinued if possible [17,18]. Sometimes bradycardia secondary to obstructive sleep apnea can disappear as a result of adequate treatment [3].

- Mild hyperkalemia S-Potassium 5.5 - 6.5 mmol/L, moderate 6.5 - 7.5 mmol/L, severe > 7.5 mmol/L.
- Nausea, palpitations, muscular pain.
- ECG-pathology: pointy T-waves, increased QRS-width, ST changes, bradycardia.
- S-Potassium > 7.0 mmol/L and/or ECG-changes necessitates urgent treatment.
- Falsely increased potassium may result from hemolysis/stasis.

**Treatment of hyperkalemia**

- Calcium-Sandoz® iv 10 ml 9 mg/ml during 3 minutes.
- Discontinue potassium-sparing pharmaceutical agents.
- Fast acting insulin 20 E in 1000 ml 5% Glucose, 100-200 ml/hour.
- Beta-adrenergic inhalation or subcutaneous Bricanyl® (7 μg/kg).
- Isotonic Sodium chloride solution (0.9 mg/ml).
- Sodium bicarbonate solution in case of acidosis.
- Loop-diuretics iv (furosemide 40 - 60 mg).
- Resin administered orally or rectally (Resonium® 15g 3 - 4 times daily).
- Hemodialysis in severe cases.

*Table 4: Hyperkalemia.*

### Permanent pacemaker

When a reversible underlying cause is ruled out, the indication for pacemaker therapy rests on the severity of the bradycardia (type of block and symptoms) rather than the etiology. Asymptomatic sinus arrest with R-R intervals of less than 6 seconds seldom calls for pacemaker implantation. Pacemaker therapy is generally only required in SSS when there is associated symptoms, and it has not been proven to decrease the risk of death. If pacemaker therapy is indicated, AV-synchronous pacing (DDD-mode) is recommended over VVI due to the reduced risk of atrial fibrillation and possibly stroke and heart failure [19-22]. A two-fold increase of the risk of reoperation during long-term follow-up has been seen with AAI compared to DDD due to unknown AV-nodal disease at time of implant or progressive conduction disturbance [23]. In AV-block, on the other hand, pacemaker therapy improves the prognosis and is recommended even for asymptomatic patients with high degree AV-block (II type 2 and III), regardless if permanent or intermittent. Whether or not patients with AV-block II type 1 should receive pacemaker is controversial, unless they are symptomatic or the block is in or below the bundle of His. Progression to a block of higher degree is more likely when the QRS complexes are wide [1].
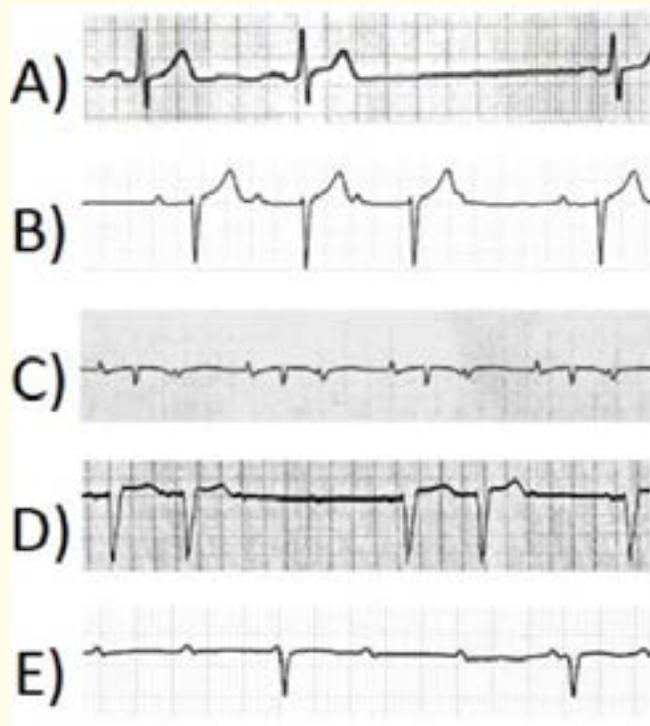
**Figure 1:** *A. Sinus node dysfunction (sinus arrest or sinoatrial block). B. AV-block II, Mobitz type I (Wenckebach), successive prolongation of PR-time until loss of QRS. C. AV-block II, 2:1 block. D. AV-block II, Mobitz type II. Constant PR-time and intermittent absence of QRS. E. AV-block III (no conduction between atrium and ventricles, escape rhythm 37 beats per minute.*
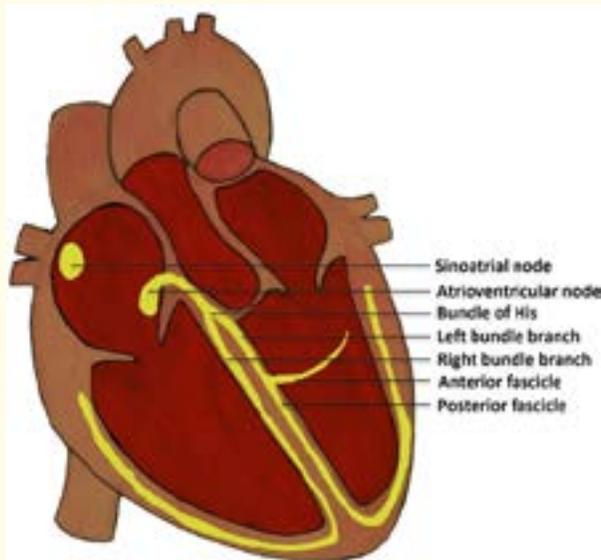


**Figure 2:** *Cardiac conduction system. In the sinus node an impulse is generated and propagated over the atriae before delay in the AV-node. Then the impulse is lead through the His bundle and then simultaneously via the right and left branches. There are different varieties, but typically the left branch is divided in an anterior and posterior part. Next, the impulses are lead via Purkinje fibers. The conduction is influenced by autonomic nervous system and perfusion.*
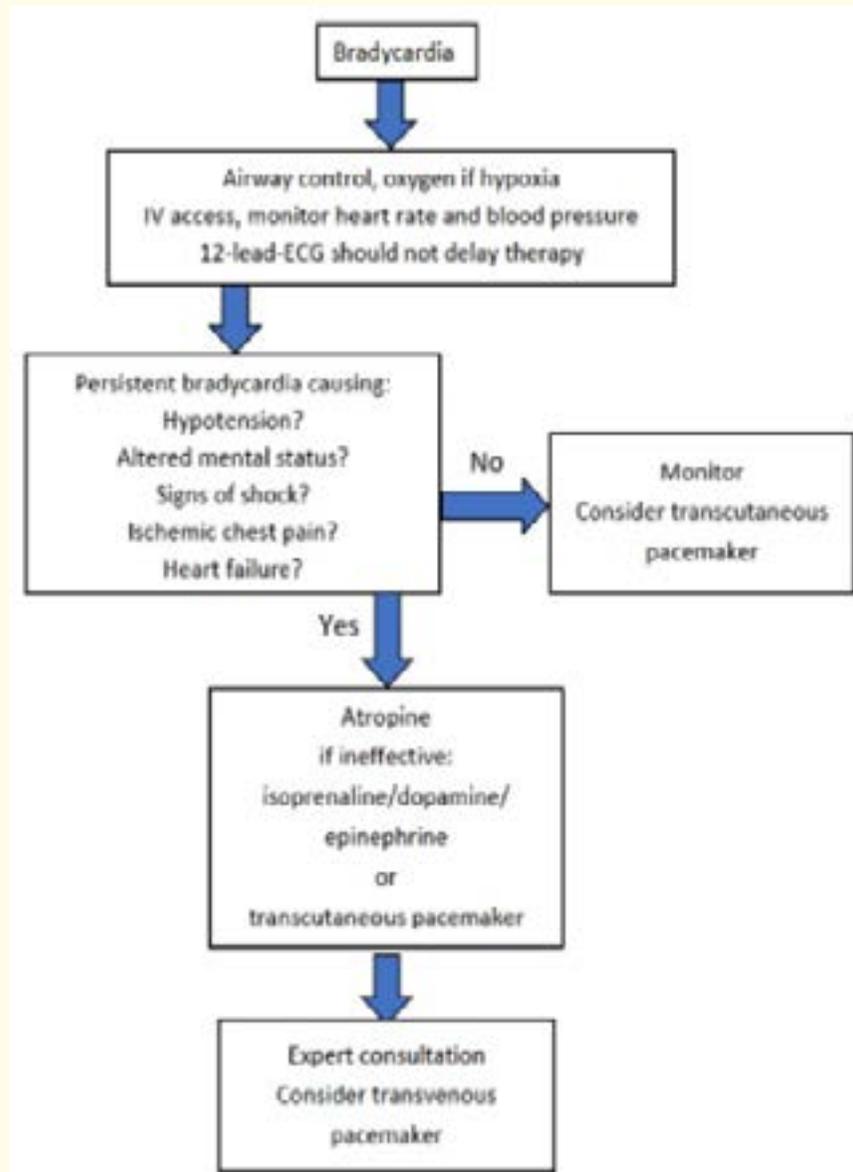
***Figure 3:*** *Management of life threatening bradycardia. Source: Based on guidelines from American Heart Association [9].*

## Prognosis

The natural course of severe bradycardias can be read about in older studies, from the days when pacemaker therapy was new. Concerning AV-block, there are multiple observational studies that clearly show that pacemaker therapy increases survival [1]. The long-term prognosis varies depending on the underlying cause of bradycardia. Regardless of the cause, emergency treatment can be lifesaving, and it is the same for any etiology.

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