ATRIOVENTRICULAR AND INTRAVENTRICULAR BLOCK

ATRIOVENTRICULAR BLOCK

Definitions

First degree AV block is characterized by a PR interval >200 ms (Table 1). A narrow QRS complex indicates that the block is most probably at the AV nodal, whereas wide QRS can be seen with block either at the node or His-Purkinje system.

Second degree AV block is characterized by P waves not conducted to the ventricles.

Type I AV block (Mobitz I or Wenckebach) shows progressively increasing PR intervals until a P wave fails to be conducted to the ventricles. Type I AV block can be physiological in athletes, resulting from heavy physical training, and occasionally in young people. It may also be normally seen during sleep in patients with high vagal tone.[1]

Type II AV block (Mobitz II) shows ***consecutive***, non-conducted P waves without visible changes in the PR interval (ie AV conduction time) before and after the blocked impulse, provided there is normal sinus rhythm. Block is infranodal at the His-Purkinje level.

Third degree (complete) AV block. No P wave is conducted to the ventricles and ventricular contraction is maintained by an escape nodal or intra- or infra-hisian rhythm.

Epidemiology

The prevalence of first-degree AV block in healthy, middle-aged subjects ranges from 1 to 8%. Mobitz II block in healthy individuals is very rare (0.003%), whereas the prevalence of third-degree AV block in the general population varies between 0.04 to 0.6%.[2] In an extensive Danish Registry of young patients, the estimated incidence of developing AVB before 50 years of age was 17.7/year/million inhabitants throughout a 20-year nationwide study period. The aetiology of AV block was identified in only half of the patients. The most frequent causes were complications to cardiac surgery (15.3%), and congenital AVB or congenital heart disease (9.0% and 4.2%, respectively).[3]

Aetiology and Pathophysiology

Causes of AV block are presented in Table 2. Medications and conditions associated with bradycardia in general are presented in the Chapter on Disorders of the CCS. Genetic causes

of AV nodal disease by means of mutations in ion channel encoding genes are presented in the Chapters on Genetic Channelopathies. In the young, complications of cardiac surgery (15%) and congenital AV block (9%) are the most common causes. However in up to 50% of patients no aetiology is identified.[3]

Progressive Cardiac Conduction Disease (PCCD) is diagnosed in the presence of unexplained progressive conduction abnormalities in young (<50 years) individuals with structurally normal hearts in the absence of skeletal myopathies especially if there is a family history of PCCD. [4] It was initially described by Lenegre and Lev who hypothesized that progressive conduction defects were due to a primary degenerative disease of unknown origin that was exaggerated by aging. There has been now evidence that progressive conduction system disease has genetic, infective, and autoimmune origins.[4] Myocardial ischemia and infarction, hypertension, inherited degenerative disease affecting the conduction system (***Lev and Lenegre disease***), ***sarcoidosis, rheumatic disorders (rheumatoid arthritis, scleroderma), congenital heart deformities, neuromuscular disorders, aortic stenosis, cardiac tumors, infections such as Lyme disease and Chagas disease, electrolyte abnormalities, myocarditis, endocarditis, cardiac surgery, sleep apnea, myotonic dystrophies, type 2 diabetes mellitus,*** and ***catheter ablation procedures*** may affect the conduction system and cause permanent of paroxysmal AV block. ***Cardiac sarcoidosis*** and a mild form of ***giant cell myocarditis*** are the cause for more than 25% of initially unexplained AV block in young and middle-aged adults. These patients are at high risk for adverse cardiac events.[5] ***Lyme*** is a common tick-borne disease transmitted to humans through the bite of the Ixodes tick. [6,7] The causative bacterium is usually *Borrelia burgdorferi*, and Borrelia antibodies may be sought with ELISA and confirmed by a Western blot assay in cases of otherwise unexplained acute AV block. The disease is characterized by an early localized infection, with erythema migrans, fever, fatigue, headache, myalgias, and arthralgias. Erythema migrans usually begins as a small erythematous papule or macule that appears at the site of the tick bite 1 to 2 weeks later and subsequently enlarges. It may occur anywhere on the body surface, although common sites are the groin, axilla, waist, back, lower extremities, and, in children, the head and neck. [6] An early disseminated infection may follow days to weeks later, with neurologic (such as facial nerve pulsy or aseptic meningitis), musculoskeletal, or cardiovascular symptoms and multiple erythema migrans lesions. Late Lyme disease, with intermittent swelling and pain of 1 or more joints (especially knees) may also occur.[8] However, although Lyme borreliosis is the most common tick-borne infectious disease in North America and in countries with moderate climates in Eurasia, Lyme carditis is rare. AV block is the most common presentation of Lyme carditis (90%), with high-degree AV block accounting for two thirds of the cases.[7] Lyme carditis involves the heart with a clinical picture similar to acute rheumatic fever, and responds to antibiotics such as IV ceftriaxone or oral doxycycline, amoxicillin, and

cefuroxime for 2 to 6 weeks, depending on the presentation. In treated patients, complete heart block generally usually resolves within 2 weeks of antibiotics.[7] Recurrent *erythema migrans* after antibiotic treatment is caused by reinfection rather than relapse of the original infection,[9] and persistent arthritis is probably due to infection-induced autoimmunity. Thus, prolonged antibiotic therapy for the so-called "chronic Lyme disease" is not justified.[10] **Radiation-associated cardiac disease** may result in AV conduction abnormalities even years following radiation exposure.[11] Cardiac lesions related to the immunogenetic marker **HLA-B57**, can be found with or without rheumatologic manifestations such as spondyloarthropathies and various forms of vasculitis, and have been associated with AV block and aortic regurgitation.[12] Anti-Ro/La antibodies are especially prevalent in autoimmune diseases but are also relatively frequent in healthy adults. Seropositivity is positively associated with adult cardiac conduction disturbances and cardiac rhythm disturbances, regardless of the presence of concurrent autoimmune disease.[13] Congenital AV block is discussed in the Chapter on Specific Conditions. Type 2 diabetes mellitus is independently associated with complete AV block.[14] **Mutations** (mainly SCN5A) associated with AV conduction disease are presented in Table 3. **Vagally induced AV block**, ie by vomiting, is a benign phenomenon.

Syncope (Adams-Stokes) and death may occur due to complete heart block if an escape rhythm at a lower level than the site of block does not intervene. Torsade de pointes may also occur and probably represents the leading cause of death in unpaced patients. QT and Tpe (peak to T end) intervals as well as the Tpe/QT ratio, T-wave alternans, reversed asymmetry of the T wave, a triphasic T wave, and biphasic T waves where the amplitude of the second peak is greater than the amplitude of the first peak (long QT syndrome type 2–like notched T wave) are predictors of development of torsade. [15]

Diagnosis

First degree AV block

1. Atrial premature beats may produce prolonged PR intervals due to refractory fast pathway of the AV node.
2. Several drugs such as beta blockers, non-dihydropyridine calcium channel blockers, flecainide and amiodarone may prolong the PR interval.
3. In the middle-aged (30-59 years) general population first degree AV block may be a transient phenomenon, and is not associated with increased mortality.

Second degree AV block

1. Nonconducted atrial premature beats may mimic AV block.
2. Concealed His bundle or ventricular extrasystoles confined to the specialized conduction

system without myocardial depolarization can also produce electrocardiographic patterns that mimic type I and/or type II block (pseudo-AV block). Occasionally, retrograde P waves may be present.

3. The diagnosis of type II block cannot be established if the first post-block P wave is followed by a shortened PR interval or is not discernible.

4. An apparent narrow QRS type II block may be a type I block with miniscule increments of the PR interval.

5. If the PR is >300 ms, the block is in the AV node. If the PR is <160 ms, the block is in the bundle of His or bundle branches.[16]

6. A pattern resembling a narrow QRS type II block in association with an obvious type I structure in the same recording effectively rules out type II block because the coexistence of both types of narrow QRS block is exceedingly rare.[17]

7. If the QRS complex demonstrates bundle branch block, the site of conduction can be anywhere in the AV conduction system. If the QRS complex is normal, block is in the AV node or bundle of His, whereas a type I block with bundle branch block barring acute myocardial infarction is infranodal in 60% to 70% of cases.

8. If the conduction improves with atropine or exercise or worsens with carotid sinus massage, the block is in the AV node. If the conduction worsens with atropine or exercise or improves with carotid sinus massage, the block is in His or bundle branches.[16]

9. A 2***:1 AV block*** is not necessarily a type II block, and it can be nodal or infranodal. It can be high-grade if the sinus rate is low or even normal response of the AV node to an atrial tachycardia or flutter. A 2:1 block may mimic sinus bradycardia when the nonconducted P waves fall on the preceding T waves (Figure 1).

10. Although the diagnosis of type II block is possible with an increasing sinus rate, absence of sinus slowing is an important criterion of type II block because a vagal surge can cause simultaneous sinus slowing and AV nodal block, which can superficially resemble type II block. Significant PR prolongation before and after block and prolonged PP intervals during ventricular asystole are indicative of vagal block that is benign condition rather than ***paroxysmal AV block*** ie pause- or bradycardia-dependent block, that is potentially dangerous for syncope.[18] It is also called ***phase 4 AV block***, but it may not depend on phase 4 depolarization.[19] The presence of paroxysmal AV block can be suspected by observing prolonged 3° AVB without sinus slowing that starts after a premature depolarization, but a definitive diagnosis requires His bundle recordings.[17]

11. ***Tachycardia-dependent AV block*** involves conduction block of early premature impulses is a physiological phenomenon often due to high atrial rate. It is also called ***phase 3 AV block*** and has been attributed to refractoriness due to phase 3 repolarization, but this is disputable.[19]

Third degree AV block

1. Unless if the escape rhythm is lower than the sinus rate (and usually <45 bpm) complete AV block cannot be differentiated from AV dissociation.
2. In patients younger than 60 years with unexplained second-degree (Mobitz II) or third-degree AV block, sarcoidosis should be considered.[20] In this case, immunosuppression can be useful.

Electrophysiologic testing may be useful for the identification of the site and type of block, and for the detection of latent AV conduction disturbances. A prolonged HV interval (>70 ms) may [21] [22] or may not [23] indicate increased risk for development of advanced block. Thus, an HV interval >70 ms is a nonspecific predictor of development of high-grade AV block, [24] whereas an HV>100 ms is highly predictive but insensitive.[25] The value of adenosine or ATP testing for induction of latent AV block is not established.[25,26] However, there has been evidence that induction of cardiac pauses (due to AV block or sinoatrial block >10 sec by an IV bolus of 20 mg ATP) indicates the need for DDD pacing.[27,28] Adenosine may also be used but its effects are not identical with those of ATP.[28] Procainamide or atrial pacing to stress the His-Purkinje system have also been used but their diagnostic yield is limited.[25] Initial evaluation of patients with suspected AV block is presented in Figure 2. Indications for electrophysiology study in second degree AV block are presented in Table 4 and for genetic testing in progressive conduction disease in Table 5. Evaluation of bradycardia, in general, is also discussed in the Chapter on Disorders of the CCS.

Therapy

Acute therapy

Recommendations are provided in Tables 6-8, as well as in the Chapter on Disorders of the CCS.

Chronic therapy

Marked ***first-degree AV block*** (PR> or =0.30 s) can produce a clinical condition similar to that of the pacemaker syndrome. Clinical evaluation often requires a treadmill stress test because patients are more likely to become symptomatic with mild or moderate exercise when the PR interval cannot adapt appropriately. In patients with marked first-degree AV block with LV systolic dysfunction it would seem prudent to consider a biventricular DDD device.[1] First-degree AV block during cardiac resynchronization therapy (CRT) predisposes to loss of ventricular resynchronization during biventricular pacing because it favors the initiation of electrical "desynchronization" especially in association with a relatively fast atrial rate, and a relatively slow programmed upper rate. In patients with myotonic dystrophy type I, and PR > 200 milliseconds, QRS > 100 milliseconds, or both, pacing is indicated when HV >70 ms and

improves survival.[22]

In ***type I second-degree AV block***, the indications for permanent pacing are controversial, unless the conduction delay occurs below the AV node or there are symptoms. However, type I block is not usually benign in patients > or = 45 years of age, and pacemaker implantation may be considered, even in the absence of symptomatic bradycardia or organic heart disease.[29]

Type II second-degree AV block progresses to complete heart block, particularly when the QRS is wide, and infranodal blocks require pacing regardless of form or symptoms.[30,31] In patients with cardiac sarcoidosis, a pacemaker (preferably with an ICD) should be implanted even if the AV block reverses transiently.[20]

In ***third degree block*** pacing improves survival.[30,31]

Indications for permanent pacing are presented in Tables 9-13 and Figure 3. See also Chapter 68.

Exercise-provoked distal atrioventricular block if not due to ischemia has a poor prognosis and should be paced.[32]

Genetic therapies and biological pacemakers by means of viral-based or stem cell-based gene delivery systems as well as engineered electrical conduction tracts are under study. [33,34]

Choice of pacing mode in AV block

Mode selection for permanent pacing is presented in Table 13. DDD pacing has not been shown to offer reduced rates of cardiovascular death or stroke, or even quality of life compared to VVI pacing.[35-37] However, there may be a significant reduction in the development of atrial fibrillation with physiological pacing,[35] although not in all trials,[37] as well as avoidance of pacemaker syndrome that may be seen in 5-25% of patients with VVI pacing. An AAI-DDD changeover mode (SafeR trial) reduced ventricular pacing in a general pacemaker population, but had no effect on hospitalization for HF, AF, or cardioversion, when compared with DDD (ANSWER trial).[38] VDD pacing is a viable alternative to DDD pacing in patients with high degree AV block and normal sinus node function, offering lower cost, high reliability, and abbreviated implantation time.[39]

Main problem is the degradation of atrial sensing ability with time.

Prolonged ventricular dyssynchrony induced by long-term RV apical pacing is associated with deleterious LV remodeling, and deterioration of both LV diastolic and systolic function.[40-43] **RV apical pacing** imposes an increased risk of HF diagnosis particularly during the first 30 and 180 days post-implantation.[44,45] **RV septal pacing** sites are beneficial by means of intraventricular synchrony and LV function.[46-48] In patients with AV block, septal pacing is superior to apical RV pacing by means of preserving left ventricular function,[49,50] at least in patients without a previous anteroseptal myocardial infarction, although no benefit

over apical pacing has been shown in randomized, but without a long-term follow-up, studies.[51-53] **Biventricular pacing** may be preferable,[54] especially in patients with reduced LVEF. In the BLOCK-HF trial, biventricular was preferable to RV pacing in the presence of LVEF<50% and AV block, but the potential of increased LV lead-related complications should be considered (BLOCK-HF trial).[55]

Conduction system pacing has emerged as a more physiological alternative to right ventricular pacing for AV block, and is also being used in selected cases for cardiac resynchronization therapy.[56-59] The term denotes His bundle pacing, LBB pacing, and deep septal stimulation that is often acceptable in terms of similarity with nonselective LBB pacing (Figure 4).[59,60]

Non-selective His bundle pacing is characterized by depolarization starting immediately after the pacing stimulus. There is a pseudo-delta wave in the surface electrogram and/or local potential fused with the pacing stimulus in the endocardial electrogram.

Selective His bundle pacing is characterized by an isoelectric interval in the surface ECG in all 12 leads and/or discrete potential after the pacing stimulus in the endocardial electrogram.

Selective LBB pacing may result in capture of the pre-divisional LBB with simultaneous activation of all of its fascicles or capture of one of the LBB fascicles or its distal arborization. *Pre-divisional LBB pacing* is characterized by a pacing spike followed by a short isoelectric interval before QRS onset. A discrete local ventricular electrogram may be seen between the pacing stimulus and QRS. There is RBBB morphology with normal axis and a rapid initial upstroke. *Fascicular pacing* is characterized by short potential to QRS interval (<25 ms), often with an abnormal paced QRS axis (usually superior and different compared with the native QRS axis). Transition in QRS morphology with fixation beats of QR/rSR' during intraseptal lead implantation indicate capture of the LBB. The time to peak R wave in V_6 (VsRWPT) is <75 ms (native narrow QRS or RBBB) or <80 ms (LBBB, intraventricular conduction delay, RBBB+fascicular block, wide escape rhythm, asystole), and the V_6-V_1 interpeak interval >44 ms.

Non-selective LBB pacing (left septal pacing) is indicated by a QRS starting immediately after the pacing spike without an isoelectric interval. A pseudo-delta wave indicating direct myocardial activation may be shown. There is no delay between the spike and ventricular electrogram, and usually the time to peak R wave in V_6 (VsRWPT) is <85 ms (native narrow QRS or RBBB) or <100 ms (LBBB, intraventricular conduction delay, RBBB+fascicular block, wide escape rhythm, asystole), and the V_6-V_1 interpeak interval >33 ms.

Deep septal pacing is indicated by a paced QRS slightly wider than with LBB area pacing, but narrower than that during right ventricular septal pacing. The stimulus to V6 R-wave peak

time (V6RWPT) is longer, there is usually no terminal R-wave in lead V1 and no features of left conduction system capture.[56,57]

Specific ***His bundle pacing*** is superior to RV pacing for AV block,[61] and offers comparable or even better results to biventricular pacing by means of cardiac resynchronization (Table 14). [62-64] In a systematic review for the 2018 ACC/AHA/HRS GL on bradycardia, among patients with LVEF >35%, the LVEF remained preserved or increased with either biventricular or His-bundle pacing compared with right ventricular pacing, but patient-centered clinical outcome improvement appeared to be limited primarily to patients who have chronic atrial fibrillation with rapid ventricular response rates and have undergone atrioventricular node ablation.[65] Potential problems with His-bundle pacing are higher pacing thresholds, lower R-wave amplitudes, and the potential to develop distal conduction block. The potential necessity of a "backup" ventricular lead has been raised, and complications rate is higher than that of RV or LBBB pacing.[31] ***Left bundle branch pacing*** has emerged as an alternative method for delivering physiological pacing to achieve electrical synchrony of the left ventricle, especially in patients with atrioventricular block (Figure 5).[56,61,66-69] LBBP-CRT has demonstrated greater LVEF improvement than BiVP-CRT in heart failure patients.[70-72] LBB pacing has also improved left ventricular ejection fraction, with a higher implant success rate, and fewer late lead-related complications than His bundle pacing in patients with atrial fibrillation and heart failure post-atrioventricular junction ablation.[73] The procedure for achieving selective LBB pacing may be cumbersome. The expected activation patterns for differentiation between selective may not take into account inapparent fascicular disease,[74] and differentiating between the two is not always straightforward.[75,76] Complications such as coronary injury or septal perforation to the left ventricle with potential thromboembolic sequelae may occur in up to 8% of patients.[66,74,77]

In patients with normal or mildly deteriorated left ventricular ejection fraction, a randomized comparison on 75 patients showed that conduction system pacing (His, LBB or deep septal pacing) results in improved preservation of cardiac function and reduced admissions for heart failure compared with apical pacing over a 6-month follow-up.[60] Left bundle branch pacing leads to a more synchronous activation of the left ventricle than non-selective septal pacing due to capture of the specialized conduction system, and for cardiac resynchronization, is superior to left septal pacing.[78] In patients with a high pacing burden with high risk of cardiac dysfunction, LBB pacing has significantly reduced the risk of the composite outcome, driven primarily by a decreased risk of pacing-induced cardiomyopathy, and is associated with better echocardiographic improvements and clinical function compared to right septal pacing.[79] Left ventricular septal (LVS) pacing, ie capture of the left side of the interventricular septum without direct activation of the left bundle, may inadvertently occur in up to 25% of cases aimed at achieving selective LBB pacing.[66,68] Animal and human studies

have indicated that both pacing strategies seem to maintain electrical and mechanical activation of the left ventricle to a near physiologic level without significant differences.[46,80,81] In a recent meta-analysis, patients with reduced LVEF and wide QRS duration, LBB pacing demonstrates superior efficacy compared with LVS pacing, but in patients with preserved LVEF and narrow QRS duration, the efficacy of LBB and LVS pacing appears to be similar.[81] In the MELOS Reloaded trial on patients with AV block and other comorbidities, inability to selectively capture the LBB was associated with increased mortality.[68]

ATRIOVENTRICULAR DISSOCIATION

AV dissociation is independent beating of the atria and ventricles due to:

1. Slowing of the sinus rate which allows escape of a subsidiary or latent pacemaker.
2. Acceleration of a latent pacemaker, as happens in non-paroxysmal AV junctional tachycardia or VT.
3. Complete heart block with junctional or ventricular escape rhythm.

INTRAVENTRICULAR BLOCK

Definition

This is block at any level of the His-Purkinje system and is usually due to ischemic heart disease and hypertension as well as the causes described in AV block. It may also be seen in apparently healthy persons. Definitions have been provided by AHA/ACC/HRS in 2009. [82] A summary is presented in Table 15. Current criteria for LBBB include a QRS duration ≥ 120 ms and this threshold is also used for CRT recommendations. However, certain patients may not have true complete LBBB, but likely have a combination of left ventricular hypertrophy and left anterior fascicular block, and stricter criteria such as a QRS duration ≥ 140 ms for men and ≥ 130 ms for women, along with mid-QRS notching or slurring in ≥ 2 contiguous leads, have been recently proposed.[83]

Left bundle branch block (LBBB) and **right bundle block (RBBB)** lead to interventricular dyssynchrony. The prevalence of bundle-branch block increases from 1% at age 50 years to 17% at age 80 years, resulting in a cumulative incidence of 18%.[84]

RBBB may display normal axis or 180^0 (common type or Wilson block). Left or extreme right axis deviation suggest coexistent hemiblock. Pure RBBB and bifascicular blocks are associated with S waves in leads I and aVL. An ECG pattern of RBBB in lead V1 with absent

S wave in leads I and aVL indicates concomitant LBB delay and bilateral block.[85]

Both RBBB and incomplete RBBB are two to three times more common among men than women.[86] RBBB can be seen in hypertensives, and as opposed to LBBB, was considered not to be associated with increased mortality. There has been evidence, however, that complete RBBB (but not incomplete) is associated with increased cardiovascular risk and all-cause mortality.[33] In patients with LVEF<35%, RBBB is associated with significantly greater scar size than LBBB and occlusion of a proximal LAD septal perforator causes RBBB.[87] In mirror-image dextrocardia or dextroversion (see Chapter 1), relocating the V_1 through V_6 leads (with the V_1-V_6 leads placed in the V_{6R}-V_{3R}, V_1, and V_2 positions) is necessary for ECG interpretation. Thus, an apparently RBBB may indicate LBBB in this setting (Figure 6).[88]

LBBB may display normal or more often left axis deviation that implies worse prognosis. Right axis deviation may be seen in dilated cardiomyopathy. Septal conduction during LBBB is heterogenous. There may be complete block, usually high at the left-sided His fibers (left intrahisian block, and most amenable to corrective His bundle pacing), and less usually more distally at the left bundle level, or conduction slowing distally to Purkinje fibers.[89] Preexisting left bundle branch block in the absence of clinical evidence of heart disease is rare but carries an increased mortality.[90] The presence of an initial r wave of >= 1 mm in lead V1 usually indicates intact left to right ventricular septal activation,[91] unless if the r wave is due to a large septal scar. In this case and ventricular activation occurs without right-to-left septal activation resulting in initial positivity in lead V1 during LBBB because of unopposed endo-epicardial activation of the right ventricular wall.[92] Newly acquired LBBB is most often a hallmark of advanced hypertensive and/or ischemic heart disease, and carries a 10-fold increase in mortality.[93] Exercise-induced LBBB may be seen in the presence of coronary artery disease.[94] Idiopathic or iatrogenic LBBB may induce electro-mechanical dyssynchrony and LV dysfunction.[95] Clinical suspicion for painful LBBB syndrome may be raised in individuals whose chest pain paroxysms correlate temporally with intermittent LBBB after ruling out myocardial ischemia, although it rarely coexists with coronary artery disease. Additional ECG features that may be associated with painful LBBB syndrome are an inferior axis and low S/T wave ratio in the precordial leads (<1.8).[96]

The trifascicular arrangement of the left bundle branch has called into question the concept of hemiblocks. Traditionally, however, **fascicular block (left anterior hemiblock - LAH, or left posterior hemiblock-LPH)** are being described and lead to intraventricular dyssynchrony.[97] ***Left anterior hemiblock*** is more common in men and increases in frequency with advancing age (0.9% to 6.2% in the general population)[90] (Figure 7). Evidence is presented regarding the relationship of spontaneous closure of ventricular septal defects, which may explain the finding of this and other conduction defects in young populations.

Isolated left anterior hemiblock is a relatively frequent finding in subjects devoid of evidence of structural heart disease. Conversely, isolated ***left posterior hemiblock*** is a very rare finding (0.1%).[90] Its prognostic significance is unknown and is commonly associated with right bundle-branch block, and there is great propensity to develop complete atrioventricular block and Adams-Stoke seizures (Figure 8).[98]

LAH (left axis deviation with Q in I and aVL) and LPH (right axis deviation with Q in inferior leads) may mimic or mask anterior or inferior infarctions.

Bifascicular block refers to LBBB or RBBB plus a hemiblock.

Trifascicular block refers to block of both the left and right bundles or to first degree AV block with additional bifascicular block.

Patients with bifascicular or trifascicular conduction defects have a 4.9% cumulative incidence of high-degree AV block at 5 years (17% if they present with syncope).[23]

Atypical intraventricular conduction defects refer to wide QRS without any typical ECG pattern and usually occur in patients with ischemic or non-ischemic heart failure. Prolonged QRS duration in a standard 12-lead ECG is associated with increased mortality in a general population, with intraventricular conduction delay being most strongly associated with an increased risk of arrhythmic death.[99] Subjects with prolonged QRS durations, even without bundle branch block, are at increased risk for future pacemaker implantation. Such individuals may warrant monitoring for progressive conduction disease.[100]

Investigations

Evaluation of patients is presented in Table 16 and Figure 9.

Therapy

Pacing is indicated in the presence of syncope (Table 17 and Figures 10 and 11) particularly in the presence of a prolonged HV interval. Up to 14% of patients with BBB and preserved LV function may have induced SVT or VT at electrophysiology study.[101] In patients without syncope, the rate of progression to high degree AV block is low and there is no non-invasive technique with a high predictive value. An HV interval >100 ms, or the demonstration of intra- or infra-Hisian block during incremental atrial pacing at a pacing rate >150 bpm, is predictive for the development of high-grade AV block, but the sensitivity of these findings is low. Wireless monitoring devices may be useful in the presence of inconsistent symptoms.[102] Permanent pacing apart from preventing future symptoms, however, has been found to have no beneficial effect on survival.

References

1. Barold SS, et al. First-degree atrioventricular block. Clinical manifestations, indications for pacing, pacemaker management & consequences during cardiac resynchronization. *J Interv Card Electrophysiol*. 2006;17:139-152. doi: 10.1007/s10840-006-9065-x
2. Virani SS, et al. Heart Disease and Stroke Statistics-2020 Update: A Report From the American Heart Association. *Circulation*. 2020;141:e139-e596. doi: 10.1161/CIR.0000000000000757
3. Rudbeck-Resdal J, et al. Aetiologies and temporal trends of atrioventricular block in young patients: a 20-year nationwide study. *Europace*. 2019;21:1710-1716. doi: 10.1093/europace/euz206
4. Katritsis D. *Progressive cardiac conduction disease.* . 7th ed. Elsevier; 2018.
5. Kandolin R, et al. Cardiac sarcoidosis and giant cell myocarditis as causes of atrioventricular block in young and middle-aged adults. *Circ Arrhythm Electrophysiol*. 2011;4:303-309. doi: 10.1161/CIRCEP.110.959254
CIRCEP.110.959254 [pii]
6. Shapiro ED. Clinical practice. Lyme disease. *N Engl J Med*. 2014;370:1724-1731. doi: 10.1056/NEJMcp1314325
7. Yeung C, et al. Diagnosis and Treatment of Lyme Carditis: JACC Review Topic of the Week. *J Am Coll Cardiol*. 2019;73:717-726. doi: 10.1016/j.jacc.2018.11.035
8. Stanek G, et al. Lyme borreliosis. *Lancet*. 2012;379:461-473. doi: 10.1016/S0140-6736(11)60103-7
S0140-6736(11)60103-7 [pii]
9. Nadelman RB, et al. Differentiation of reinfection from relapse in recurrent Lyme disease. *N Engl J Med*. 2012;367:1883-1890. doi: 10.1056/NEJMoa1114362
10. Berende A, et al. Randomized Trial of Longer-Term Therapy for Symptoms Attributed to Lyme Disease. *N Engl J Med*. 2016;374:1209-1220. doi: 10.1056/NEJMoa1505425
11. Desai MY, et al. Prevention, Diagnosis, and Management of Radiation-Associated Cardiac Disease: JACC Scientific Expert Panel. *J Am Coll Cardiol*. 2019;74:905-927. doi: 10.1016/j.jacc.2019.07.006
12. Bergfeldt L. HLA-B27-associated cardiac disease. *Ann Intern Med*. 1997;127:621-629.
13. Akuka A, et al. Association of anti-Ro seropositivity with cardiac rhythm and conduction disturbances. *Eur Heart J*. 2022. doi: 10.1093/eurheartj/ehac516
14. Haxha S, et al. Type 2 diabetes mellitus and higher rate of complete atrioventricular block: a Danish Nationwide Registry. *Eur Heart J*. 2023;44:752-761. doi: 10.1093/eurheartj/ehac662
15. Cho MS, et al. Electrocardiographic predictors of bradycardia-induced torsades de pointes in patients with acquired atrioventricular block. *Heart Rhythm*. 2015;12:498-505. doi: 10.1016/j.hrthm.2014.11.018
16. Josephson ME, et al. Episodic dizziness in a 74-year-old woman. *Heart Rhythm*. 2014;11:2329-2330. doi: 10.1016/j.hrthm.2014.08.018
17. Barold SS, et al. Second-degree atrioventricular block: a reappraisal. *Mayo Clin Proc*. 2001;76:44-57. doi: S0025-6196(11)62080-6 [pii]
10.4065/76.1.44
18. Lee S, et al. Paroxysmal atrioventricular block. *Heart Rhythm*. 2009;6:1229-1234. doi: 10.1016/j.hrthm.2009.04.001
S1547-5271(09)00397-X [pii]
19. El-Sherif N, et al. Paroxysmal atrioventricular block: are phase 3 and phase 4 block mechanisms or misnomers? *Heart Rhythm*. 2009;6:1514-1521. doi: 10.1016/j.hrthm.2009.06.025
20. Birnie DH, et al. HRS expert consensus statement on the diagnosis and management of arrhythmias associated with cardiac sarcoidosis. *Heart Rhythm*. 2014;11:1305-1323. doi: 10.1016/j.hrthm.2014.03.043
21. Dhingra RC, et al. Significance of the HV interval in 517 patients with chronic bifascicular block. *Circulation*. 1981;64:1265-1271.
22. Wahbi K, et al. Electrophysiological study with prophylactic pacing and survival in adults with myotonic dystrophy and conduction system disease. *JAMA*. 2012;307:1292-1301. doi: 10.1001/jama.2012.346
307/12/1292 [pii]
23. McAnulty JH, et al. Natural history of "high-risk" bundle-branch block: final report of a prospective study. *N Engl J Med*. 1982;307:137-143. doi: 10.1056/NEJM198207153070301
24. Sheldon RS, et al. Electrophysiology studies for predicting atrioventricular block in patients with syncope: A systematic review and meta-analysis. *Heart Rhythm*. 2021;18:1310-1317. doi: 10.1016/j.hrthm.2021.04.010
25. Katritsis D, et al. Electrophysiological testing for the investigation of bradycardias. *Arrh Electrophysiol Rev*. 2017;6:24-28.
26. Brignole M, et al. Lack of correlation between the responses to tilt testing and adenosine triphosphate test and the mechanism of spontaneous neurally mediated syncope. *Eur Heart J*. 2006;27:2232-2239. doi: ehl164 [pii]
10.1093/eurheartj/ehl164
27. Brignole M, et al. Adenosine-induced atrioventricular block in patients with unexplained syncope: the diagnostic value of ATP testing. *Circulation*. 1997;96:3921-3927.

28. Flammang D, et al. Treatment of unexplained syncope: a multicenter, randomized trial of cardiac pacing guided by adenosine 5'-triphosphate testing. *Circulation*. 2012;125:31-36. doi: 10.1161/CIRCULATIONAHA.111.022855
CIRCULATIONAHA.111.022855 [pii]
29. Shaw DB, et al. Is Mobitz type I atrioventricular block benign in adults? *Heart*. 2004;90:169-174.
30. Kusumoto FM, et al. 2018 ACC/AHA/HRS Guideline on the Evaluation and Management of Patients With Bradycardia and Cardiac Conduction Delay. *JACC*. 2018. doi: 10.1016/j.jacc.2018.10.044
31. Glikson M, et al. 2021 ESC Guidelines on cardiac pacing and cardiac resynchronization therapy. *Eur Heart J*. 2021. doi: 10.1093/eurheartj/ehab364
32. Chokshi SK, et al. Exercise-provoked distal atrioventricular block. *Am J Cardiol*. 1990;66:114-116. doi: 0002-9149(90)90749-Q [pii]
33. Boink GJ, et al. HCN2/SkM1 gene transfer into canine left bundle branch induces stable, autonomically responsive biological pacing at physiological heart rates. *J Am Coll Cardiol*. 2013;61:1192-1201. doi: 10.1016/j.jacc.2012.12.031
34. Cingolani E, et al. Engineered electrical conduction tract restores conduction in complete heart block: from in vitro to in vivo proof of concept. *J Am Coll Cardiol*. 2014;64:2575-2585. doi: 10.1016/j.jacc.2014.09.056
35. Lamas GA, et al. Quality of life and clinical outcomes in elderly patients treated with ventricular pacing as compared with dual-chamber pacing. Pacemaker Selection in the Elderly Investigators. *N Engl J Med*. 1998;338:1097-1104. doi: 10.1056/NEJM199804163381602
36. Kerr CR, et al. Canadian Trial of Physiological Pacing: Effects of physiological pacing during long-term follow-up. *Circulation*. 2004;109:357-362. doi: 10.1161/01.CIR.0000109490.72104.EE
01.CIR.0000109490.72104.EE [pii]
37. Toff WD, et al. Single-chamber versus dual-chamber pacing for high-grade atrioventricular block. *N Engl J Med*. 2005;353:145-155. doi: 353/2/145 [pii]
10.1056/NEJMoa042283
38. Stockburger M, et al. Long-term clinical effects of ventricular pacing reduction with a changeover mode to minimize ventricular pacing in a general pacemaker population. *Eur Heart J*. 2015;36:151-157. doi: 10.1093/eurheartj/ehu336
39. Shurrab M, et al. VDD vs DDD pacemakers: a meta-analysis. *Can J Cardiol*. 2014;30:1385-1391. doi: 10.1016/j.cjca.2014.04.035
40. Fang F, et al. Deleterious effect of right ventricular apical pacing on left ventricular diastolic function and the impact of pre-existing diastolic disease. *Eur Heart J*. 2011;32:1891-1899. doi: 10.1093/eurheartj/ehr118
ehr118 [pii]
41. Cicchitti V, et al. Heart failure due to right ventricular apical pacing: the importance of flow patterns. *Europace*. 2016;18:1679-1688. doi: 10.1093/europace/euw024
42. Tops LF, et al. The effects of right ventricular apical pacing on ventricular function and dyssynchrony implications for therapy. *J Am Coll Cardiol*. 2009;54:764-776. doi: 10.1016/j.jacc.2009.06.006
43. Khurshid S, et al. Incidence and predictors of right ventricular pacing-induced cardiomyopathy. *Heart Rhythm*. 2014;11:1619-1625. doi: 10.1016/j.hrthm.2014.05.040
44. Tayal B, et al. Incidence of heart failure after pacemaker implantation: a nationwide Danish Registry-based follow-up study. *Eur Heart J*. 2019;40:3641-3648. doi: 10.1093/eurheartj/ehz584
45. Huizar JF, et al. Abnormal Conduction-Induced Cardiomyopathy. *JACC*. 2023.
46. Rijks J, et al. Physiology of Left Ventricular Septal Pacing and Left Bundle Branch Pacing. *Card Electrophysiol Clin*. 2022;14:181-189. doi: 10.1016/j.ccep.2021.12.010
47. Shimony A, et al. Beneficial effects of right ventricular non-apical vs. apical pacing: a systematic review and meta-analysis of randomized-controlled trials. *Europace*. 2012;14:81-91. doi: 10.1093/europace/eur240
48. Weizong W, et al. Effects of right ventricular nonapical pacing on cardiac function: a meta-analysis of randomized controlled trials. *Pacing Clin Electrophysiol*. 2013;36:1032-1051. doi: 10.1111/pace.12112
49. Flevari P, et al. Long-term nonoutflow septal versus apical right ventricular pacing: relation to left ventricular dyssynchrony. *Pacing Clin Electrophysiol*. 2009;32:354-362. doi: 10.1111/j.1540-8159.2008.02244.x
50. Victor F, et al. A randomized comparison of permanent septal versus apical right ventricular pacing: short-term results. *J Cardiovasc Electrophysiol*. 2006;17:238-242. doi: 10.1111/j.1540-8167.2006.00358.x
51. Janousek J, et al. Permanent cardiac pacing in children: choosing the optimal pacing site: a multicenter study. *Circulation*. 2013;127:613-623. doi: 10.1161/CIRCULATIONAHA.112.115428
52. Kaye GC, et al. Effect of right ventricular pacing lead site on left ventricular function in patients with high-grade atrioventricular block: results of the Protect-Pace study. *Eur Heart J*. 2015;36:856-862. doi: 10.1093/eurheartj/ehu304
53. Kypta A, et al. Long-term outcomes in patients with atrioventricular block undergoing septal ventricular lead implantation compared with standard apical pacing. *Europace*. 2008;10:574-579. doi: 10.1093/europace/eun085

54. Chan JY, et al. Biventricular pacing is superior to right ventricular pacing in bradycardia patients with preserved systolic function: 2-year results of the PACE trial. *Eur Heart J*. 2011;32:2533-2540. doi: 10.1093/eurheartj/ehr336
55. Curtis AB, et al. Biventricular pacing for atrioventricular block and systolic dysfunction. *N Engl J Med*. 2013;368:1585-1593. doi: 10.1056/NEJMoa1210356
56. Burri H, et al. EHRA clinical consensus statement on conduction system pacing implantation: executive summary. Endorsed by the Asia-Pacific Heart Rhythm Society (APHRS), Canadian Heart Rhythm Society (CHRS) and Latin-American Heart Rhythm Society (LAHRS). *Europace*. 2023;25:1237-1248. doi: 10.1093/europace/euad044
57. Vijayaraman P, et al. Cardiac Conduction System Pacing: A Comprehensive Update. *JACC Clin Electrophysiol*. 2023. doi: 10.1016/j.jacep.2023.06.005
58. Chow CLD, et al. Clinical Outcomes of Conduction System Pacing vs Right Ventricular Septal Pacing in Atrioventricular Block: The CSPACE Randomized Controlled Trial. *J Am Coll Cardiol*. 2025;86:563-573. doi: 10.1016/j.jacc.2025.06.043
59. Whinnett Z, et al. Physiological pacing: mechanisms, clinical indications, and perspectives. *Eur Heart J*. 2025. doi: 10.1093/eurheartj/ehaf440
60. Gonzalez-Matos CE, et al. Conduction System Stimulation to Avoid Left Ventricle Dysfunction. *Circ Arrhythm Electrophysiol*. 2024;17:e012473. doi: 10.1161/CIRCEP.123.012473
61. Tan ESJ, et al. Clinical Outcomes in Conduction System Pacing Compared to Right Ventricular Pacing in Bradycardia. *JACC Clin Electrophysiol*. 2023;9:992-1001. doi: 10.1016/j.jacep.2022.10.016
62. Vinther M, et al. A Randomized Trial of His Pacing Versus Biventricular Pacing in Symptomatic HF Patients With Left Bundle Branch Block (His-Alternative). *JACC Clin Electrophysiol*. 2021. doi: 10.1016/j.jacep.2021.04.003
63. Vinther M, et al. A Randomized Trial of His Pacing Versus Biventricular Pacing in Symptomatic HF Patients With Left Bundle Branch Block (His-Alternative). *JACC Clin Electrophysiol*. 2021;7:1422-1432. doi: 10.1016/j.jacep.2021.04.003
64. Huang W, et al. His-bundle pacing vs biventricular pacing following atrioventricular nodal ablation in patients with atrial fibrillation and reduced ejection fraction: A multicenter, randomized, crossover study-The ALTERNATIVE-AF trial. *Heart Rhythm*. 2022;19:1948-1955. doi: 10.1016/j.hrthm.2022.07.009
65. Slotwiner DJ, et al. Impact of Physiologic Pacing Versus Right Ventricular Pacing Among Patients With Left Ventricular Ejection Fraction Greater Than 35%. A Systematic Review for the 2018 ACC/AHA/HRS Guideline on the Evaluation and Management of Patients With Bradycardia and Cardiac Conduction Delay
. *JACC*. 2018.
66. Jastrzebski M, et al. Left bundle branch area pacing outcomes: the multicentre European MELOS study. *Eur Heart J*. 2022;43:4161-4173. doi: 10.1093/eurheartj/ehac445
67. Hua W, et al. Advances of Implantation Techniques for Conduction System Pacing. *JACC Clin Electrophysiol*. 2022;8:1587-1598. doi: 10.1016/j.jacep.2022.09.022
68. Jastrzebski M, et al. Left bundle branch area pacing vs right ventricular pacing for atrioventricular block: the MELOS RELOADED study. *Eur Heart J*. 2025. doi: 10.1093/eurheartj/ehaf699
69. Qian Z, et al. Left Bundle-Branch Pacing versus Right Ventricular Pacing for Atrioventricular Block. *NEJM*. 2026.
70. Diaz J, C., et al. Left Bundle Branch Area Pacing Versus Biventricular Pacing as Initial Strategy for Cardiac Resynchronization *JACC*. 2023.
71. Vijayaraman p, et al. Comparison of Left Bundle-Branch Area Pacing to Biventricular Pacing in Candidates for Resynchronization Therapy. *JACC*. 2023.
72. Gin J, et al. Improved outcomes of conduction system pacing in heart failure with reduced ejection fraction: A systematic review and meta-analysis. *Heart Rhythm*. 2023;20:1178-1187. doi: 10.1016/j.hrthm.2023.05.010
73. Mengxing C. Left Bundle Branch Pacing Postatrioventricular Junction Ablation for Atrial Fibrillation: Propensity Score Matching With His Bundle Pacing *Circulation AE*. 2022.
74. Cano O, et al. Left bundle branch pacing versus left ventricular septal pacing as a primary procedural endpoint during left bundle branch area pacing: Evaluation of two different implant strategies. *J Cardiovasc Electrophysiol*. 2024;35:120-129. doi: 10.1111/jce.16128
75. Zhu K, et al. Criteria for differentiating left bundle branch pacing and left ventricular septal pacing: A systematic review. *Front Cardiovasc Med*. 2022;9:1006966. doi: 10.3389/fcvm.2022.1006966
76. Jastrzebski M, et al. Transseptal Transition Patterns During Left Bundle Branch Area Lead Implantation. *JACC Clin Electrophysiol*. 2024;10:2471-2484. doi: 10.1016/j.jacep.2024.07.025
77. Ponnusamy SS, et al. Electrophysiological characteristics of septal perforation during left bundle branch pacing. *Heart Rhythm*. 2022;19:728-734. doi: 10.1016/j.hrthm.2022.01.018
78. Diaz JC, et al. Left Bundle Branch Pacing vs Left Ventricular Septal Pacing vs Biventricular Pacing for Cardiac Resynchronization Therapy. *JACC Clin Electrophysiol*. 2023. doi: 10.1016/j.jacep.2023.10.016
79. Qiu N, et al. Randomized Trial of Left Bundle Branch Pacing vs Right Ventricular Pacing in Vulnerable Cardiac Function. *J Am Coll Cardiol*. 2026;88:188-201. doi: 10.1016/j.jacc.2026.03.161
80. Zhou Y, et al. Left ventricular septal pacing versus left bundle branch pacing in the treatment of atrioventricular block. *Ann Noninvasive Electrocardiol*. 2022;27:e12944. doi: 10.1111/anec.12944

81. Putra ICS, et al. Efficacy and safety of left bundle branch pacing compared with left ventricular septal pacing: A systematic review and meta-analysis. *Heart Rhythm O2*. 2025;6:1335-1355. doi: 10.1016/j.hroo.2025.06.006
82. Surawicz B, et al. AHA/ACCF/HRS recommendations for the standardization and interpretation of the electrocardiogram: part III: intraventricular conduction disturbances: a scientific statement from the American Heart Association Electrocardiography and Arrhythmias Committee, Council on Clinical Cardiology; the American College of Cardiology Foundation; and the Heart Rhythm Society: endorsed by the International Society for Computerized Electrocardiology. *Circulation*. 2009;119:e235-240. doi: 10.1161/CIRCULATIONAHA.108.191095
CIRCULATIONAHA.108.191095 [pii]
83. Strauss DG, et al. Defining left bundle branch block in the era of cardiac resynchronization therapy. *Am J Cardiol*. 2011;107:927-934. doi: 10.1016/j.amjcard.2010.11.010
84. Eriksson P, et al. Bundle-branch block in a general male population: the study of men born 1913. *Circulation*. 1998;98:2494-2500.
85. Tzogias L SL, Williams AJ, Morris KE, Mahlow WJ, Fogel RI, Olson, et al. Electrocardiographic features and prevalence of
bilateral bundle-branch delay. . *Circ Arrhythm Electrophysiol* 2014 Aug;7(4):640-4.
86. Bussink BE, et al. Right bundle branch block: prevalence, risk factors, and outcome in the general population: results from the Copenhagen City Heart Study. *Eur Heart J*. 2013;34:138-146. doi: 10.1093/eurheartj/ehs291
87. Strauss DG, et al. Right, but not left, bundle branch block is associated with large anteroseptal scar. *J Am Coll Cardiol*. 2013;62:959-967. doi: 10.1016/j.jacc.2013.04.060
88. Chang Q, et al. Bundle Branch Block Site in a Patient With a Right-Lying Heart and Wide QRS Complex. *JAMA Intern Med*. 2018. doi: 10.1001/jamainternmed.2018.6709
89. Upadhyay GA, et al. Intracardiac Delineation of Septal Conduction in Left Bundle Branch Block Patterns: Mechanistic Evidence of Left Intra-Hisian Block Circumvented by His Pacing. *Circulation*. 2019. doi: 10.1161/CIRCULATIONAHA.118.038648
90. Tan NY, et al. Left Bundle Branch Block: Current and Future Perspectives. *Circ Arrhythm Electrophysiol*. 2020;13:e008239. doi: 10.1161/CIRCEP.119.008239
91. Padanilam BJ, et al. The surface electrocardiogram predicts risk of heart block during right heart catheterization in patients with preexisting left bundle branch block: implications for the definition of complete left bundle branch block. *J Cardiovasc Electrophysiol*. 2010;21:781-785. doi: 10.1111/j.1540-8167.2009.01714.x
JCE1714 [pii]
92. Wellens HJ. Is the left bundle branch really blocked when suggested by the electrocardiogram? *Europace*. 2012;14:619-620. doi: 10.1093/europace/eur401
eur401 [pii]
93. Flowers NC. Left bundle branch block: a continuously evolving concept. *J Am Coll Cardiol*. 1987;9:684-697.
94. Anand V, et al. Things Are Not Always as They Seem: Multimodality Exercise Assessment in the Evaluation of Dyspnea. *Circulation*. 2021;143:2502-2507. doi: 10.1161/CIRCULATIONAHA.121.053615
95. Auffret V, et al. Idiopathic/Iatrogenic Left Bundle Branch Block-Induced Reversible Left Ventricle Dysfunction: JACC State-of-the-Art Review. *J Am Coll Cardiol*. 2018;72:3177-3188. doi: 10.1016/j.jacc.2018.09.069
96. Shvilkin A, et al. Painful left bundle branch block syndrome: Clinical and electrocardiographic features and further directions for evaluation and treatment. *Heart Rhythm*. 2016;13:226-232. doi: 10.1016/j.hrthm.2015.08.001
97. Perez-Riera AR, et al. The tetrafascicular nature of the intraventricular conduction system. *Clin Cardiol*. 2019;42:169-174. doi: 10.1002/clc.23093
98. Elizari MV, et al. Hemiblocks revisited. *Circulation*. 2007;115:1154-1163. doi: 115/9/1154 [pii]
10.1161/CIRCULATIONAHA.106.637389
99. Aro AL, et al. Intraventricular conduction delay in a standard 12-lead electrocardiogram as a predictor of mortality in the general population. *Circ Arrhythm Electrophysiol*. 2011;4:704-710. doi: 10.1161/CIRCEP.111.963561
100. Cheng S, et al. Relation of QRS width in healthy persons to risk of future permanent pacemaker implantation. *Am J Cardiol*. 2010;106:668-672. doi: 10.1016/j.amjcard.2010.04.021
S0002-9149(10)00957-4 [pii]
101. Moya A, et al. Diagnosis, management, and outcomes of patients with syncope and bundle branch block. *Eur Heart J*. 2011;32:1535-1541. doi: 10.1093/eurheartj/ehr071
ehr071 [pii]
102. Walsh JA, 3rd, et al. Novel wireless devices for cardiac monitoring. *Circulation*. 2014;130:573-581. doi: 10.1161/CIRCULATIONAHA.114.009024