Woldemar Mobitz and His 1924 Classification of Second-Degree Atrioventricular Block

Mark E. Silverman, MD, MACP, FRCP; Charles B. Upshaw, Jr, MD; Helmut W. Lange, MD

Abstract—Woldemar Mobitz, an early 20th century German internist, analyzed arrhythmias by graphing the relationship of changing atrial rates and premature beats to AV conduction. Through an astute mathematical approach, he was able to classify second-degree atrioventricular block into 2 types, subsequently referred to as Mobitz type I (Wenckebach) and Mobitz type II (Hay). Type I AV block was most often due to digitalis and was reversible. There were no associated pathological findings. Type II AV block frequently progressed to complete AV block and was associated with seizures, death, and pathological findings. (Circulation. 2004;110:1162-1167.)

Key Words: Mobitz ■ arrhythmias ■ conduction ■ heart block

“It may appear astonishing to the clinician that the results presented here are seemingly based on purely mathematical considerations. However, the idea that all theoretical concepts of rhythm disturbances developed so far are derived from measuring the recorded tracings, and correlating numerical data will give the same approval for this method of reasoning in regard to the field of clinical medicine as it has already been given for the methods of pure chemistry and physics in regard to other fields.”

—Woldemar Mobitz

Woldemar Mobitz, an early 20th century German internist with a mathematical inclination for analyzing arrhythmias, is remembered eponymically for his 1924 classification of second-degree atrioventricular (AV) block into 2 types, subsequently referred to as Mobitz type I (Wenckebach) and Mobitz type II (Hay).

Biography

Mobitz was born May 31, 1889, in St. Petersburg, Russia, the son of a prominent surgeon. His family moved to Tübingen in southwest Germany before his sixth birthday. His father had died at a young age, and Mobitz was raised by his mother and an uncle. He attended the Gymnasium at Meiningen, Saxony, equivalent to high school and college-level study, graduating in 1908. Mobitz began medical studies at the University of Munich, from which he graduated in 1914.

Initially, he worked in Berlin and Halle in surgical clinics, and then he completed his internship at the first medical clinic at Munich. His activities during and after World War I are unknown. In 1921, he was a lecturer in the first medical clinic at the University of Munich, directed by Professor Ernst von Romberg. His interests included various internal medical topics centering mainly on cardiovascular disease and arrhythmia.2–4

In February 1922, Mobitz presented an example of AV dissociation.5 Two months later, he lectured on the question of “automation of the AV node” in a patient with AV dissociation.6 He published a report on the effect of extrasystoles in humans with regard to their contribution to interference of the cardiac rhythm in 1923.7 Later that year, he published his important article on automation of the AV node, in which he introduced the term “interference-dissociation.”8

At the Medical Convention for Internal Medicine in Vienna in April 1923, Mobitz spoke about the nature of time intervals between atrial and ventricular action.9 In July 1923, at the meeting of the Association of Munich Specialists of Internal Medicine, he lectured on AV conduction disturbances in humans.10 This was the occasion on which he first classified second-degree AV block into type I and type II. He authored his classic article on “partial block” of conduction between the atrium and ventricle in human hearts in 1924, commenting on their pathophysiological differences.1 Between 1923 and 1930, Mobitz also published articles on congenital and acute porphyria; heart failure due to primary pulmonary arteriosclerosis; regulation of the circulation; enhancement of action potentials; a valve for mechanical production of alveolar air; and the correlation of respiration, circulation, and oxygen consumption during physical work, as well as 6 articles on determination of the pulse volume of humans as analyzed by inhalation of ethyl iodide.11–17

Having achieved recognition for his medical accomplishments, Mobitz was invited in 1928 by Professor Hans Eppinger, Jr, to join the faculty of the University of Freiburg, where he remained for 15 years, becoming tenured in 1939. Mobitz suffered from laryngeal tuberculosis, and there were reservations about his health that led to quarrels with fellow
staff member Siegfried Josef Thannhauser. Mobitz was promoted to senior assistant physician in March 1934; Thannhauser, who was 4 years older than Mobitz, opposed the promotion. Thannhauser was dismissed from the Freiburg clinic on April 17, 1934, and Mobitz became the head when it was determined that he did not present a health risk. For uncertain reasons, Mobitz was replaced within 10 days by Otto Bickenbach, a leader of the National Socialist party in Munich. In 1943, Mobitz left the University of Freiburg and was appointed Director of the State Medical Clinic in Magdeburg, where he stayed until 1945, when Germany was occupied by the combined American, British, and Soviet Union military forces. In 1946, he returned to the University of Freiburg, where he remained employed until his death on April 11, 1951, after a long illness, at age 61 years. His medical publications after World War II included a study of the differential diagnosis of lung infiltrates and new uses of isotopes in medicine.18,19

Mobitz was a quiet, scholarly man with a delicate sense of justice, considered to be an excellent clinician and investigator though burdened by chronic illness. His mind was crystal clear and endowed with mathematical precision, which he applied brilliantly to his study of cardiac arrhythmias and conduction disturbances. In spite of his important medical achievements and high intellect, he never received any major honors or attained his highest goal, a chair at a German Medical University. This may have been owing to his chronic illness or because of his personality, which brought him into conflict with his peers. Described as lonely and introverted (he lived alone and never married), he had difficulty with interpersonal relations. Despite a thorough search, a picture of him could not be found.

Prior Observations on Second-Degree (“Partial”) AV Block

Walter Gaskell, a physiologist experimenting between 1879 and 1883 at the Cambridge Physiological Laboratory in England, removed a portion of the atrial muscle of a tortoise and noted “...if the block is more severe, then, instead of every contraction passing the blocking point, only every second contraction is able to pass.”20 He called this rhythmic phenomenon “partial block,” and he was the first to differentiate “partial” from “complete block.” (George J. Romanes, working at the same time at Cambridge, was the first to use the term “block” in studies observing the contraction movements of the jellyfish.) In 1899, 4 years before the introduction of the ECG by Willem Einthoven, Karel Wenckebach of the Netherlands reported a patient with a recurrent irregular cardiac rhythm whose ECG showed irregular atrial activity, P waves with different morphologies, and variations of the PR and RP intervals.1 His mathematical analysis demonstrated that there was “a systematic relation between the length of the PR interval and the distance of the atrial activation to the preceding ventricular beat [ie, the RP interval].... The shorter the latter, the longer lasting is the conduction [ie, the PR interval].” He stated that “the ventricular beats with normal ECG complexes must be conducted” even though “the conduction time varies between 0.12 and 0.31 sec.” The corresponding preceding RP intervals varied between 0.15 and 0.44 seconds. He continued, “...the fact that the conduction has different velocity or the latency has different length... is based on different degrees of recovery either in conductivity as measured in conduction velocity, or reactivity measured as latency of that precise portion of the heart to which the stimulus is being transmitted.” Postulating that there was variable anterograde AV conduction velocity as a result of a variable recovery time of the AV node and bundle, as initially described by Hermann Straub of Munich in 1918, Mobitz showed that “the speed of recovery during diastole can be depicted as a steady curve like all analogous phenomena in nature.” He demonstrated this graphically by plotting the curvilinear relationships of both anterograde and retrograde conduction (Figure 1).

Mobitz believed that his insight into PR/RP reciprocity could contribute to the understanding of periodicity of AV block as described earlier by Wenckebach.1 He observed that the PR interval and the following RP interval were constant provided that the atrial rate remained unchanged. By graphing the relationship of changing atrial rates to AV conduction, he found that the PR interval lengthened as the atrial rate increased (Table). The PR interval remained constant and normal at a steady atrial rate of 105 bpm (Figure 2, graph A). At a regular atrial rate of 154 bpm, he observed that “the [straight] line no longer intersects the curve. [Figure 2, graph B] “This means that the atrium has exceeded the highest rate which the Aschoff node can follow.” Wenckebach periodicity developed at an atrial rate of 154 bpm with increased dropped “systoles” at 162 bpm (Figure 3, graph C) and at 176 bpm. At projected atrial rates of 231 and 300 bpm, (Figure 3, graph D), he surmised that greater degrees of AV block would develop with 2-to-1 AV conduction. Modern atrial pacing

Crediting Luigi Luciani of Italy as the first to describe this recurrent pattern in a frog heart preparation in 1873, Wenckebach called this form of group beating “Luciani periodicity.” In 1906, with the added advantage of the recently introduced ECG, Wenckebach documented that the PR intervals progressively lengthened before the dropped beat.24 His unraveling of this ECG phenomenon subsequently became known as “Wenckebach periodicity.” That same year, Ludwig Aschoff and Sunao Tawara in Marburg, Germany, discovered the AV node, thereby providing the anatomic substrate to the conduction abnormality described by Wenckebach.25,26

Observations by Mobitz on Second-Degree (Partial) AV Block

In 1924, Mobitz reported a 40-year-old woman with an irregular cardiac rhythm whose ECG showed irregular atrial activity, P waves with different morphologies, and variations of the PR and RP intervals.1 His mathematical analysis demonstrated that there was “a systematic relation between the length of the PR interval and the distance of the atrial activation to the preceding ventricular beat [ie, the RP interval]... The shorter the latter, the longer lasting is the conduction [ie, the PR interval].” He stated that “the ventricular beats with normal ECG complexes must be conducted” even though “the conduction time varies between 0.12 and 0.31 sec.” The corresponding preceding RP intervals varied between 0.15 and 0.44 seconds. He continued, “...the fact that the conduction has different velocity or the latency has different length... is based on different degrees of recovery either in conductivity as measured in conduction velocity, or reactivity measured as latency of that precise portion of the heart to which the stimulus is being transmitted.” Postulating that there was variable anterograde AV conduction velocity as a result of a variable recovery time of the AV node and bundle, as initially described by Hermann Straub of Munich in 1918, Mobitz showed that “the speed of recovery during diastole can be depicted as a steady curve like all analogous phenomena in nature.” He demonstrated this graphically by plotting the curvilinear relationships of both anterograde and retrograde conduction (Figure 1).

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studies have shown that this is the usual response of the AV node when it is challenged by a progressively increased atrial pacing rate.

**Classification by Mobitz of Second-Degree (Partial) AV Block Into 2 Types**

Mobitz classified Wenckebach periodicity as a type I form of “partial [AV] block,” commenting that it had been produced experimentally in animals with digitalis, strychnine, and asphyxia and by cooling the cardiac ventricle. In humans, it was reported to most commonly be due to digitalis intoxication. He noted that type I conduction impairment was reversible, and that human autopsy studies did not usually disclose significant disease of the AV node or the bundle of His. Mobitz also observed that the QRS duration is usually normal with this type of AV block. “Those kinds (type I) which we interpret as purely functional impairments, normally do not show [changing] ventricular complexes.”

In the same paper, Mobitz also discussed the less common but more serious form of AV block as first described by John Hay of Liverpool, England, in 1906 and again later that year by Wenckebach.24,27,28 Hay kymographically recorded simultaneous jugular venous and radial arterial pulses of a 65-year-old man with a slow pulse. He observed that the a-to-c intervals of the jugular venous waves remained constant until an a wave occurred that was not followed by the c wave or a radial pulse. The pause was equal to 2 atrial pulse-wave intervals.27,28

Mobitz termed this form of abnormal conduction “type II AV block” (Figure 4) and noted the following features: (1) normal, fixed PR intervals that were present independent of the length of the preceding RP intervals; (2) random dropping of ventricular complexes that occurred without prolongation of the PR interval; (3) the pause resulting from the nonconducted P wave equaled 2 P-P intervals; and (4) the PR interval did not change after a pause. He reviewed the medical literature, commenting that type II AV block often progresses to complete AV block and is associated with Stokes-Adams attacks and death. From autopsy reports, Mobitz believed “that conduction disturbances of Type II are very likely an expression of a structural injury to the bundle.” He included the AV node as a part of the His bundle. Although bundle-branch block was not recognized electrocardiographically in humans until 1925,29 Mobitz described ventricular complexes that suggested the presence of bundle-branch block in his patients with type II AV block: (1) “Quite unique was the behavior of the ventricular complexes. They showed, although originating without exception from a supraventricular source, multiform changes in shape.” (2) “In view of the profound deviation from normal shape shown by the various types of ventricular EKG’s, larger territories involving several branches of the atrioventricular system must have been affected.” (3) “The profound variety of ventricular complexes in this case . . . suggesting a failing ventricular muscle.”

Describing the 2 types of AV block, Mobitz observed that “daily clinical experiences teaches that in transient conduction disturbances apparently due to toxicity—most often, we see them as a consequence of high-dose digitalization—exclusively those kinds of partial block are being observed, which we can derive from our curve and call Type I.” By way of contrast, he stated, “We recognize in Type II a structural

**Figure 1.** Mobitz’s “theory of variable latency” (PR interval is related to preceding RP interval and results in a steady curve). Numbers are in hundredths of a second; PR intervals are on ordinate; preceding RP intervals are on abscissa. Figure has been lightly retouched for clarity. Reprinted from Figure 2 of Mobitz,1 with permission from Springer-Verlag, © Springer-Verlag.

<table>
<thead>
<tr>
<th>P-P Interval*</th>
<th>Atrial Rate, bpm</th>
<th>PR Interval After a Pause*</th>
<th>PR Interval Before a Pause*</th>
<th>AV Conduction</th>
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<tr>
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<td>105</td>
<td>13†</td>
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<td>1:1</td>
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<tr>
<td>42</td>
<td>149</td>
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<td>39</td>
<td>154</td>
<td>13 with Wenckebach periodicity</td>
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<tr>
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<td>162</td>
<td>13 with Wenckebach periodicity</td>
<td>23</td>
<td>5:4</td>
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<tr>
<td>34</td>
<td>176</td>
<td>13 with Wenckebach periodicity</td>
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<td>4:3</td>
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<td>28</td>
<td>214</td>
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<td>20</td>
<td>300</td>
<td>19</td>
<td>...</td>
<td>2:1</td>
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*In hundredths of a second.
†No pause present at this P-P interval.
‡Atrial rate at which type I AV block develops.
process affecting the cross-sectional area of the bundle as the decisive element of the ventricular cessation.

Current Understanding of Second-Degree AV Block

Since the 1924 article by Mobitz, studies have confirmed the pathological and prognostic differences between type I and type II AV block. 

Type I AV block has been associated with digitalis, inferior myocardial infarction, heightened venous tone (as seen in sleep, vomiting, and highly trained athletes), sclerodegenerative disease affecting the AV node, congenital AV block, and myocarditis. His bundle studies have localized the site of the conduction block to the AV nodal or upper junctional region (supra His) as manifested by
Figure 4. Laddergram drawn by Mobitz showing "Cessation of systole as in Type II (despite preceding uninterrupted conduction, no stepwise prolongation in conduction time prior to the cessation.)" High-grade AV block is also present, with 2 consecutive nonconducted P waves. Numbers are in hundreds of a second; P-P interval of 75 corresponds to atrial rate of 80 bpm. Figure has been lightly retouched for clarity. Reprinted from Figure 19 of Mobitz,

a prolongation of the A-H interval. The block is usually reversible and may or may not require permanent pacing, depending on the presence of symptoms. The ECG criteria for type I AV block have not changed significantly from Wenckebach’s original observations, although frequent variations are known.\(^3\)\(^3\)\(^4\) These include (1) sequences with a high AV ratio; (2) frequently changing AV ratios; (3) variations in sinus rate; (4) presence of atrial echoes, concealed impulses, or an accelerated junctional rhythm; (5) a widening of the final cycle before the pause due to a large increment in AV nodal transit time preceding the dropped beat; (6) effects of abrupt changes in autonomic tone; (7) incremental changes in conduction too small to measure at the usual recording speed of 25 mm/s; and (8) AV block at more than 1 level.

As originally pointed out by Mobitz, type II AV block indicates permanent structural damage to the bundle branches and is associated with extensive anterior myocardial infarction or widespread sclerodenerative conduction disease. The location of type II AV block is below the His bundle (infranodal), as demonstrated by a prolonged H-V interval. High-degree or complete AV block can be anticipated, and permanent pacing is usually indicated to prevent dizziness, syncope, and death.\(^3\)\(^5\) The criteria initially developed by Mobitz were redefined in 1956,\(^6\) which led to some confusion, as discussed by Barold and Hayes.\(^3\)\(^7\)\(^8\) As they point out, Mobitz also included higher degrees of AV block, ie, 3-to-1 and 4-to-1 conduction, in addition to a single dropped P wave followed by a conducted P wave with a normal PR interval. The current definition of type II AV block includes the following: (1) The sinus rate (or the P-P interval) is constant, and there are at least 2 consecutively conducted P waves. (2) The PR interval may be normal or prolonged but remains constant. (3) There is a single nonconducted P wave associated with a constant PR interval before and after the blocked impulse. (4) The QRS interval is usually prolonged, although it can be normal. (5) The site of the AV block is infranodal.

ECGs that display a fixed 2:1 AV block cannot be easily classified; Wenckebach periodicity is suspected when the conducted P wave is associated with a borderline or prolonged PR interval and the QRS complex is narrow or when typical 3:2 AV conduction is also present. ECGs showing 3:1 and 4:1 or greater conduction ratios are now properly classified as high-grade AV block.

In 1968, Richard Langendorf and Alfred Pick wrote an editorial in Circulation as "a plea for clinical distinction between type I and type II A-V block, especially in recent myocardial infarction." They credited Mobitz for recognizing the functional nature of type I block and the organic nature of type II block, pointing out that the distinction had become blurred over the years. This editorial by highly respected electrocardiographers served to reintroduce and popularize the Mobitz classification. This was further sanctioned by a committee that revised the nomenclature and concepts of AV and intraventricular conduction in 1970 (not published until 1973), which was then redefined in 1978 by the World Health Organization. This classification of second-degree AV block, initially proposed by Mobitz, has been accepted and widely applied since that time.\(^3\)\(^8\)\(^9\) His important contribution endures as a helpful eponym, and he is also honored by the German Society for Cardiology, which awards "The Woldemar Mobitz Research Prize" for studies concerning cardiac arrhythmias.

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