Wenckebach Periods Associated with High Grade
Second Degree (2:1 and 3:1) A-V Block

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SUMMARY

An electrocardiogram (ECG) of bilateral bundle branch block (BBBB) which may be attributable to a mixture of 2:1 and 3:1 atrioventricular (A-V) block is described. The irregularity of QRS complexes with left bundle branch block (LBBB) pattern during 2:1 A-V block may be ascribable to "Wenckebach periods", which might be due either to A-V nodal or His bundle or bundle branch delay. However, it was impossible to distinguish between them precisely because appropriate His bundle studies were not performed during the active arrhythmic phase. Although the exact mechanisms involved were not established with certainty, different rates of recovery in conduction in the bundle branches in association with a marked prolongation of the refractoriness would seem to be the unique feature of this complex arrhythmia.

An ECG tracing of BBBB indicating high grade second degree (2:1 and 3:1) A-V block, in which "spontaneous" occurrence of "Wenckebach periods" with 2 consecutive blocked P waves can be observed during 2:1 A-V block, has never been reported previously as far as can be ascertained from published records.

Additional Indexing Words:
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In recent years, it has been demonstrated in some clinical cases that Wenckebach periods and block of 2 consecutive P waves can be provoked by rapid atrial pacing and the hypothesis has been suggested that either repetitive concealed conduction presumably in the A-V node or 3:2 Wenckebach periods proximal to the His bundle with resulting 3:1 A-V block is involved in such a phenomenon.

On the other hand, at the time when the ECGs show 2:1 A-V block with right bundle branch block (RBBB) pattern (and left anterior fascicular block), it has been shown in man that Wenckebach periods and block of 2 consecutive P waves can be elicited by increasing the sino-atrial rate with atropine sulfate.
intravenously or by inhalation of amyl nitrite. This phenomenon has been attributed to Wenckebach periods in the main left bundle or its posterior division and termed "alternating Wenckebach" by Halpern et al.2) A clinical case reported by Schuilenburg and Durrer3) has been described as "alternating Wenckebach" occurred in the His bundle during atrial pacing. However, an ECG tracing demonstrating "alternating Wenckebach" occurred "spontaneously" has never been reported so far as we know.

In all likelihood, an ECG tracing of BBBB indicating high grade second degree (2:1 and 3:1) A-V block, in which "spontaneous" occurrence of "Wenckebach periods" with 2 consecutive blocked P waves can be observed during 2:1 A-V block, has never been reported previously. We describe a possible example of such a case in this report.

**Case Report**

An ECG taken on May 30, 1970 (Fig. 1, left) from a 52-year-old man with complaint of palpitation showed sinus rhythm at a rate of 61/min and QRS complexes with RBBB pattern. The major axis of QRS was -30° and P-R interval was 0.16 sec. There was no evidence of cardiac failure and the presence of coronary

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**Fig. 1.** Left: May 30, 1970. Sinus rhythm at a rate of 61/min and QRS complexes with RBBB pattern. P-R, 0.16 sec. Major axis of QRS, -30°.


Right: March 10, 1972. 2:1 A-V block with LBBB pattern. P-R, 0.41 sec. Major axis of QRS, around -44°. The blocked P waves are perched on top of the T waves. Ventriculophasic sinus arrhythmia is present.
heart disease was considered to be unlikely. Transient periods of 2:1 A-V block with RBBB pattern appeared in the ECG taken on Aug. 8, 1970 and subsequent 2 ECGs recorded in Aug. 1970 changed into a fixed 2:1 A-V block with RBBB pattern. Major axis of QRS was $-30^\circ$ and the P-R interval was 0.18 sec (Fig. 1, middle). The slight shortening of the P-R interval which encloses a QRS complex is known as ventriculophasic sinus arrhythmia. Fig. 2a–2b display the tracing taken on Nov. 14, 1970. Unfortunately, the 2 strips of lead V4 in Fig. 2b are not continuous. The mechanisms underlying this complex arrhythmia will be discussed.

![Figure 2a and 2b](image)

Fig. 2a and 2b. The tracing taken on Nov. 14, 1970. Sinus arrhythmia (rate: 90–100/min) is present. The 2 strips of V4 in Fig. 2b are not continuous. The QRS complexes with RBBB pattern which always terminate “long” ventricular cycles are preceded by a P wave at a P-R interval of 0.20–0.22 sec (except beat 5 in V1-V4 of Fig. 2a), representing conducted beats related to 3:1 A-V block. Those with LBBB pattern terminating “long” ventricular cycles are always preceded by a P wave at a fixed P-R interval of 0.31 sec, also representing conducted beats related to 3:1 A-V block. Regarding the QRS complexes with LBBB pattern terminating relatively shorter ventricular cycles, it may be impossible to explain with certainty that all of them are conducted beats. The most likely explanation, nevertheless, may be a mixture of 3:1 and 2:1 A-V block. The irregularity of QRS complexes with LBBB pattern in V1-V4 of Fig. 2a (beats 3 & 4 & 5–8) and in the second half of the upper strip (beats 6 & 7 & 8–11) of Fig. 2b may represent “Wenkebach periods”.
later. Complete A-V block with a regular ventricular rhythm of 34/min developed for the first time on Nov. 17, 1970 and the escape beats showed LBBB pattern with horizontal axis. Subsequently, the ECGs recorded in Dec. 1970 showed high-grade A-V block with occasional ventricular captures representing incomplete A-V dissociation. Dissociated beats always showed LBBB pattern and occasional captures showed RBBB pattern with P-R interval of 0.24-0.26 sec or near-normal configuration with P-R interval of 0.24 sec. Each of the 10 consecutive ECGs from Feb. 6, 1971 to March 10, 1972 (Fig. 1, right) showed a fixed 2:1 A-V block with LBBB pattern (major axis of QRS about $-44^\circ$). The LBBB pattern was identical to the pattern of the escape beats observed in 1970 and ventriculophasic sinus arrhythmia was always observed. The P-R interval gradually (but varied) prolonged from 0.32 sec (Feb. 6, 1971) to 0.41 sec (March 10, 1972). An ECG recorded on March 31, 1972 again presented complete A-V block with regular escapes (rate: 30/min) of LBBB pattern which was identical to the pattern of conducted beats during 2:1 A-V block but later ECGs (Aug. 29, 1972 and Feb. 3, 1973) reverted to a fixed 2:1 A-V block with LBBB pattern. The patient developed Adams-Stokes seizures on March 18 and 19, 1973 and 6 ECGs recorded from March 24, 1973 to April 16, 1973 presented complete A-V block and escapes of LBBB pattern which was identical to the pattern of the conducted beats in the previous years. His bundle electrogram during complete A-V block with escapes of LBBB pattern (P-P: 660-750 msec, R-R: 1,460 msec) was performed on April 12, 1973 and it revealed that each A wave was followed by a His deflection with a markedly prolonged A-H (210 msec) time. The idioventricular complexes were not preceded by a H’ deflection and suggested a subsidiary pacemaker located in the ventricles. The patient had been treated with the long term oral administration of isoproterenol (90-120 mg/day) from Aug. 1970 until a permanent pacing was performed successfully on May 15, 1973.

**DISCUSSION**

In Fig. 2a, the tracing shows sinus arrhythmia (rate: 90-100/min). In standard limb leads and standard unipolar leads, the occurrence of the QRS complexes with RBBB pattern is slow and irregular and they are preceded by a P wave at a P-R interval of 0.20-0.22 sec (measured in II and aVF). In precordial leads, they are preceded by a P wave at a P-R interval of 0.20 sec (measured in V_1 and V_4) except beat 5 in V_1-V_3, reflecting a causal relationship. In the 2 (discontinuous) strips of V_4 in Fig. 2b, the QRS complexes with RBBB pattern which always terminate "long" ventricular cycles are also preceded by a P wave at a P-R interval of 0.20-0.22 sec. On these grounds alone, it may be possible to suppose that 3:1 A-V block with RBBB pattern is prevailing in the tracing.

On the other hand, the QRS complexes with LBBB pattern terminating "long" ventricular cycles are always preceded by a P wave at a fixed P-R interval of 0.31 sec. In Fig. 2a, these are represented by: beat 5 in standard limb leads, beats 2 & 3 in standard unipolar leads, beat 1 in V_1-V_3
and beats 2 (near-normal configuration) & 3 & 5 in V₄-V₆. In Fig. 2b, they are represented by: beats 4 & 8 in the upper strip and beat 2 in the lower strip.

Under these conditions, there would be ample justification for regarding that QRS complexes with RBBB pattern related to P waves at a P-R interval of 0.20-0.22 sec and those with LBBB pattern preceded by a P wave at a constant P-R interval of 0.31 sec represent conducted beats related to 3:1 A-V block. A 3:1 A-V block may represent abortive ventricular capture due to concealed A-V conduction which is manifested by a failure of subsidiary pacemaker to escape.⁴)

Regarding the QRS complexes with LBBB pattern that terminate relatively shorter ventricular cycles, it is impossible to explain with certainty that all of them are conducted beats. The most likely explanation, nevertheless, may be a mixture of 3:1 and 2:1 A-V block. The normalized QRS complexes with prolonged P-R intervals (beat 4 in V₁-V₃ and best 2 in V₄-V₆ of Fig. 2b) may represent equalization of bilateral bundle branch conduction delay.⁵)

The irregularity of QRS complexes with LBBB pattern in V₄-V₆ of Fig. 2a (beats 3 & 4 & 5–8) may represent "Wenckebach periods" associated with 2:1 A-V block. It might be noted here that the sequence of beats 3 & 4, in contradistinction to classical Wenckebach periods, begins from and ends with 2 consecutive blocked P waves. A 2:1 A-V block in which the conducted P waves show typical progressive prolongation of the P-R interval of Wenckebach type has been described as so-called "alternating Wenckebach" and it necessarily ends with (or begins from) 2 consecutive blocked P waves.⁶) Further, it has been considered to be related to a marked prolongation of both the absolute and relative refractory periods and tends to occur below the A-V node, in one of the main ventricular conducting fascicles. Therefore, one of the plausible explanations could be Wenckebach periods in the right bundle branch (RBB). However, it has been pointed out that Wenckebach type of conduction in a thin fascicle such as the RBB is rare.⁶) Further, it has been stressed that Wenckebach type of conduction in the contralateral bundle in the presence of a fixed bundle branch block pattern is extremely difficult to appreciate from the surface ECG recordings.⁷) The sequence of beats 5–8 may also represent atypical Wenckebach periods without a progressive prolongation of the P-R interval, suggesting spontaneous fluctuations of the A-V conduction time. However, as pointed out in the pertinent literature, an increase of 20 msec in the P-R interval may not be appreciated from surface ECG tracings taken at a paper speed of 25 mm/sec.⁷) Similar phenomenon which may be attributable to "Wenckebach periods" can be observed during
the second half of the upper strip of Fig. 2b (beats 6 & 7 & 8–11).

Thus, the above mentioned "Wenckebach periods" in the presence of a fixed LBBB pattern might be due either to A-V nodal or His bundle or right bundle branch delay and it was impossible to distinguish between them because appropriate His bundle studies were not performed during the active arrhythmic phase.

Examples of so-called "alternating Wenckebach" induced by increasing the sino-atrial rate with atropine sulfate intravenously or by inhalation of amyl nitrate as well as by atrial pacing have been demonstrated. However, an ECG tracing demonstrating such a phenomenon occurred "spontaneously" has never been reported previously. "Spontaneous" occurrence of Wenckebach periods terminated by more than 1 blocked P wave is rare. It appears that the first published record demonstrating "spontaneous" occurrence of Wenckebach periods terminated by several consecutive blocked P waves is the report of Langendorf and Pich. They explained the phenomenon by the conception of concealed A-V conduction. On the other hand, it has been demonstrated in some clinical cases that Wenckebach periods and block of 2 consecutive P waves can be provoked by rapid atrial pacing, resulting in 3:1 A-V block. Two explanations have been offered to interpret such a phenomenon. The first relates to the possibility of repetitive concealed conduction presumably in the A-V node (3:1 A-V block proximal to the His bundle). The second relates to the possibility of 3:2 Wenckebach periods proximal to the His bundle with resulting 3:1 A-V block (the first P being blocked distal to and the second proximal to the His bundle).

Recently, Watanabe et al. have emphasized the importance of combined intranodal and infranodal block and its possible role in the genesis of 2:1 and 3:1 A-V block varieties. In this case, therefore, it may be assumed that different levels of block can be present, eventuating in varying depths of concealed A-V conduction.

In case the QRS complexes during complete A-V block are identical to those during orthograde conduction, the possibility that BBBB as the responsible mechanism for complete A-V block would be excluded has been stressed, and the site of idioventricular pacemaker has been considered to be located above the level of bifurcation. However, it may be almost impossible to ascertain the precise localization of the idioventricular pacemaker.

Fig. 3 is a graph to illustrate the relationship between the R-P period (the time interval between the beginning of the P wave that is to be followed by a QRS complex and the preceding R wave) and the P-R interval (the A-V conduction time). Since the heart rate is slow, it may be assumed that components of the bundle branch system may have a longer refractory period.
Fig. 3. A graph to illustrate the classical R-P/P-R relationship. Note that there was a definite tendency for the A-V conduction time to be shorter and relatively constant regarding the beats related to 3:1 conduction.

than that of the A-V node. Accordingly, under these circumstances, it may be expected that sino-atrial impulses which traversed the A-V node arrive at the His bundle bifurcation when one or both of the bundle branches are still refractory. The classical R-P/P-R relationship would seem to indicate that the absolute refractory period of the left bundle branch (LBB) was prolonged to approximately 1.5 sec, and that the beginning of the relative refractory phase of the RBB was defined by the shortest R-P (approximately 0.94 sec) giving rise to conducted beats showing LBBB pattern. Accordingly, in spite of its speculative nature, it might be possible to assume that the recovery of conductivity starts earlier but proceeds slower in the RBB than in the LBB, and that retarded conduction in the RBB as well as abnormal conduction delay in the A-V node is present in the beats which are conducted with LBBB pattern.

There is a similar case reported by Spang among other cases in which similar mechanism has been considered to be operative, and his case has been described by Lepeschkin as a possible example of "unequal first degree block in both bundle branches". On the other hand, a case of BBBB showing a mixture of 2:1 and 3:1 A-V block with different P-R intervals in conducted beats has been described by Chung as an example of "unequal asynchronous second or high degree BBBB". The varying ECG patterns of BBBB have been classified by applying the same terminology for bundle branch block as for the different degrees of A-V block (first degree, second
degree, and third degree). It has been stated by those in authority\textsuperscript{15},\textsuperscript{21} that complicated forms of “unequal asynchronous second (or high) degree BBBB” may result in extremely complex arrhythmias with regularly recurring changes of P-R interval, changes in configuration of QRS (including near-normal configuration) and occasional or frequent blocked beats. Generally, “unequal” means unequal conduction times through the bundle branches, while “asynchronous” implies that the conduction of an impulse in one bundle branch occurs concomitantly with a block of an impulse in the contralateral bundle branch\textsuperscript{22}. However, such a classification of BBBB (first degree, second degree, and third degree) seems to be not needed nowadays.

According to Childers\textsuperscript{14} “advanced A-V block” includes 2:1, 3:1, and complete A-V block, while “high degree A-V block” is defined by Chung\textsuperscript{21} as the term to indicate that the A-V conduction ratio is 3:1 or more. On the other hand, other terms such as “high grade second degree block (2:1, 3:1)”\textsuperscript{23} “high-grade A-V block\textsuperscript{24},\textsuperscript{25} (or high grade block)\textsuperscript{24},\textsuperscript{26} and “higher grades of second degree A-V block”\textsuperscript{27} appear in the recent literatures. At this moment, however, to discuss the terminology may introduce unnecessary complications.

In conclusion, this complex arrhythmia in Fig. 2a-2b was considered to be an instance of BBBB indicating high grade second degree (2:1 and 3:1) A-V block. We believe this to be the first published record demonstrating “spontaneous” occurrence of “Wenckebach periods” with 2 consecutive blocked P waves during 2:1 A-V block. Although the diagnostic catheterization study and coronary arteriography were not performed, the A-V block seemed to be not associated with coronary heart disease and the involvement of the conduction system was considered to be due to sclerosis of the left side of the cardiac skeleton\textsuperscript{28}.

\textbf{References}