Analysis of variable conduction ratios into the atrioventricular node during atrial flutter: Multilevel block theory

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Introduction

Regarding variant R-R intervals during atrial flutter (AFL), sometimes a regular group beating pattern can be observed. This phenomenon is ascribed to the complex decremental conduction property into the atrioventricular node (AVN). However, determining its accurate mechanism is very difficult, because the AVN is a so-called "black box" and has multilevel conduction blocks.[1,2] Here we offer a mechanistic method to elucidate a 2-level atrioventricular (AV) block[2] based on the electrophysiology of the AV conduction system.

Case report

A 77-year-old man developed AFL during hospitalization for treatment of pneumothorax. Two rhythm strips were recorded 30 minutes apart. Figure 1 demonstrates variable AV conductions during AFL. First, in order to accurately determine the cycle length (CL) of the AFL, total intervals of 20 AFL CLs were measured. These were 4800 and 4900 ms, or AFL CL of 240 and 245 ms, as shown in Figure 1A and B, respectively. Figure 1A shows group beating with R-R intervals of 880 ms and 560 ms. Figure 1B illustrates group beating with R-R intervals of 860 ms, 560 ms, and 540 ms.

Discussion

Typical Wenckebach phenomenon in the AVN conduction shows progressive PR interval prolongation, whereas the R-R interval conversely shortens until a long pause resulting from AVN conduction block occurs. In such a very simple condition, an input into the AVN, namely the driving CL invading the AVN, can be easily visualized. On the contrary, during a regular atrial tachyarrhythmia such as AFL, determining the driving CL may be very difficult owing to multilevel AV blocks. In our case, the PR intervals following the longest R-R interval were constant and the shortest (360 ms in Figure 2A and 320 ms in Figure 2B), irrespective of a variety of AV conduction ratios. Additionally, Figure 2B shows group beating in the R-R interval, where it progressively shortens until a long pause occurs. This phenomenon has led us to hypothesize that there are 2 levels of AV block, with lower block conducting in the Wenckebach fashion.[2]

Figure 2A shows that 6 flutter cycles (numbered as 0 to 6 in Atrium) produce 2 R waves (6:2 AV conduction ratios), where the degree of AV conduction is variable. However, AV conduction time via decremental tissue after the longest

KEY TEACHING POINTS

- Wenckebach type 1 atrioventricular block observed during sinus rhythm is noticed by the presence of a ventricular rate that is just 1 less than an atrial rate. This phenomenon is considered as a simple decremental conduction property into the single level of the atrioventricular node (AVN).
- However, the rule is not applicable to a regular atrial tachyarrhythmia like an atrial flutter (AFL), which instead displays a ventricular rate that is much less than an atrial one. This implies that the AVN plays a role filtering out signals that are involved in reducing the ventricular rate. Furthermore, sometimes group beating patterns with variant ventricular cycles can be observed during an AFL.
- These mechanisms cannot be interpreted only by a theory of the single decremental conduction property of the AVN. Therefore, multilevel conduction blocks can be considered to exist into the AVN.

KEYWORDS Atrial flutter; Atrioventricular node; Group beating with variant R-R intervals; Multiple-level block theory; Variable conduction ratios; Wenckebach periodicity
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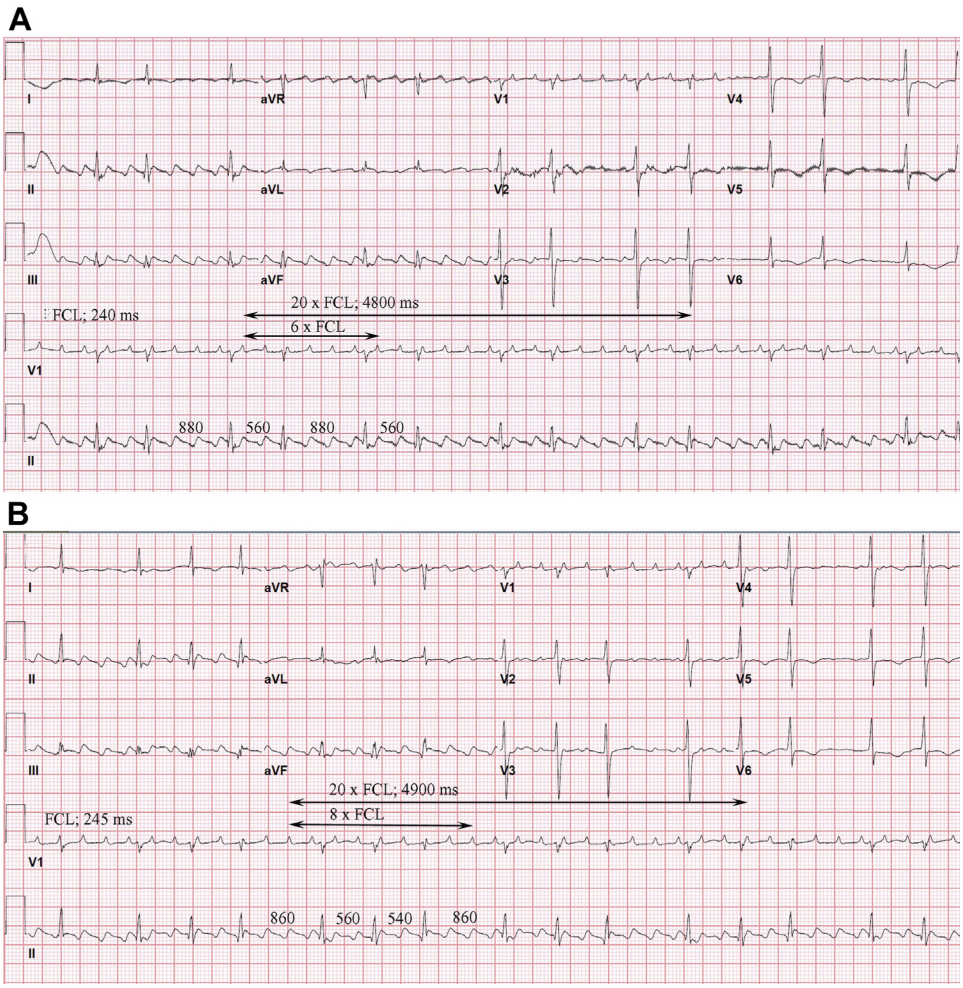

Figure 1 Surface 12-lead electrocardiogram with rhythm strips (V1 and II) showing a variety of atrioventricular conduction ratios during atrial flutter. The cycle length (CL) of atrial flutter (FCL), 20 flutter CLs in lead V_1, and R-R intervals in II are displayed. Total intervals of 20 FCLs are 4800 and 4900 ms, which make the FCLs 240 and 245 ms in panels A and B, respectively. **A:** Group beating with short-long (560-860 ms) sequence. **B:** Short-short-long (560-540-860 ms) group beating.

R-R interval (880 ms) can be assumed to return to the baseline with the constant and shortest value (T ms), notwithstanding any variable conduction ratio. Thus, measuring the interval (Y) between the first R waves following the long pause allows us to calculate the driving CL (X). During a Wenckebach periodicity, the number of inputs into the decremental tissue should be that of outputs + 1. Therefore, as shown in the ladder diagram, the Y must consist of 3 driving CLs. Here, Y, 560 + 880 ms (= 1440 ms), means 3 X. Then, the hidden driving CL is calculated as X = Y/3, namely 480 ms. This is just twice the flutter CL of 240 ms.

Similarly, Figure 2B discloses 8:3 AV conduction ratios, showing conduction ratios different from Figure 2A. However, because there are 3 R waves during the Wenckebach periodicity, the inputs must be equal to 4. Therefore, Y is 4 X and 1960 ms (= 860 + 560+ 540 ms). Namely, X is 1960/4 = 490 ms. Again, this is exactly twice the flutter CL of 245 ms.

Figure 2A and B can offer our interpretation of this AV conduction phenomenon. The variable R-R intervals are consistent with 3:1 and 4:1 Wenckebach type 1 AV block produced with the driving CL of 480 and 490 ms, respectively. Furthermore, the driving CLs are exactly twice the respective flutter CLs. These findings strongly suggest that 2:1 conduction block exists above the Wenckebach block level[1,2]; however, the exact sites of 2 levels of conduction block remain unclear.

The concept of multilevel block in the AV conduction system has previously been published. For example, Slama and colleagues[2] described 2 types of 2-level AV block. The predominant type was similar to ours, in which 2:1 AV block occurred in the upper part of the AVN and Wenckebach block occurred in the lower part of the AVN. The second type was considered to be due to Wenckebach block in the upper part and 2:1 block in the lower part of the AVN. Mendez and colleagues[3] reported a possible case of 3-level block

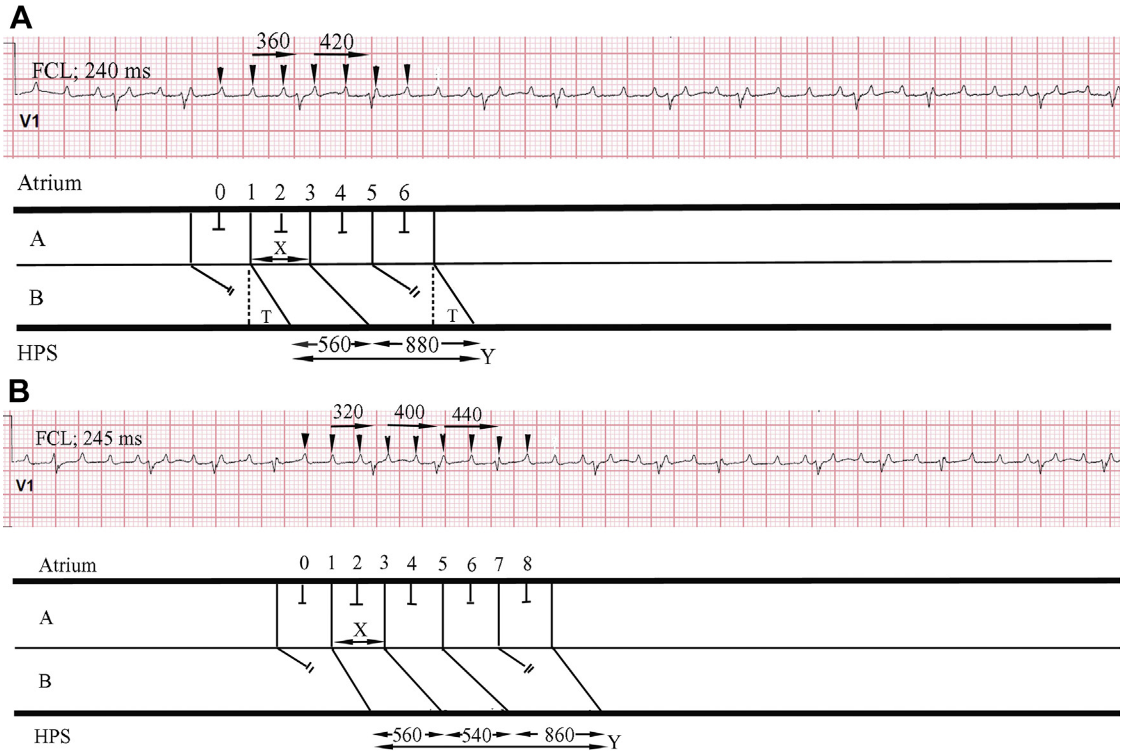

Figure 2 Analysis of a variety of atrioventricular (AV) conductions during atrial flutter (AFL) using ladder diagrams with measurement of the driving cycle length (CL) during Wenckebach periodicity. Numbers on *arrows* and *downward arrowheads* in lead V_1 indicate AV conduction times and impulses of AFL, respectively. Numbers in Atrium indicate AFL waves, of which the number 1 indicates the first AFL impulse conducting to the ventricle after the long pause. A and B = the upper and lower level into the AV node (AVN), respectively. Single and double splashes indicate conduction block at A and B into the AVN, respectively. **A:** Typical 3:1 Wenckebach type 1 AV block within the level of B is shown, where the degree of conduction is variable but the conduction time via the decremental tissue after Wenckebach type 1 AV block is assumed to return to the baseline with the constant value (T ms). In this diagram, the interval (Y) between first R waves following a long pause (880 ms) is equal to 3 times the driving CL (X), 1440 ms. Therefore, the driving CL then is calculated as X = Y/3, namely 480 ms. **B:** Also, 4:1 Wenckebach AV block is illustrated. The X is equal to Y (1960 ms = 560 + 540 + 860 ms)/4, namely 490 ms. See text for details. FCL = CL of atrial flutter; HPS = His-Purkinje system.

in the AV conduction system. However, the previous interpretations were complex and difficult to follow and their interpretations are not necessarily convincing.

As opposed to the previous studies, our mechanistic approach in interpretation is simple and based on the electrophysiology of the typical Wenckebach phenomenon. To our knowledge, this type of approach has not been published in the previous publications. Analysis of output allows us to calculate the hidden input. In our case, the output is R-R interval and the input is 2:1 AV block.

Some limitations can be presumed to exist. First, this hypothesis cannot be applied to irregular atrial tachyarrhythmias such as atrial fibrillation. Second, this hypothesis cannot be applied to cases with a rate-dependent conduction delay below the AVN. Third, no assessment of the A-level conduction physiology is precisely performed. However, this level shows a 2:1 conduction ratio; therefore, it is reasonable that we disregard the effect of the decremental conduction delay here.

Finally, the Wenckebach phenomenon of this AFL case may not be observed so rarely; therefore, we believe that it is very important that electrophysiologists understand the mechanism of Wenckebach phenomenon during regular atrial tachyarrhythmias.

Conclusion

Seemingly, group beating with variant R-R intervals during AFL resembles complicated conduction patterns into the AVN; however, on the basis of the 2-level conduction block theory into the AVN, its mechanism can frequently be interpreted.

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