Temporal Alternation of Atrial Flutter Sounds

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SUMMARY
A case of atrial flutter is reported in which the hearing of “systoles en écho” led to the recognition in the phonocardiogram of a regularly alternating time interval between successive atrial sounds during the ventricular standstill caused by stimulation of the carotid sinus. A possible explanation is proposed involving alternating pathways of atrial excitation.

Additional Indexing Words:
Atrial conduction pathways  Atrial excitation  Systoles en écho
Internodal tracts  Circus movement

THERE HAS RECENTLY BEEN great interest in the structure and function of the atria. Old controversies about the presence of special conducting tissue in atrial muscle have been revived. There is some electrophysiological evidence for pathways of rapid conduction through the atria, and it is no longer possible to accept without question the doctrine that excitation spreads from the sinus node over the surfaces of the atria like the ripples from a stone thrown into a pond.

The nature of the electrical excitation of the atria in atrial flutter is still uncertain, and recent reviews have summarized the evidence for the two main alternative theories: repetitive discharge of an atrial ectopic focus,1 or circus movement.2

Fresh evidence has appeared about the origin of the atrial sounds heard during the long diastoles in atrial flutter with high grade atrioventricular (A-V) block.3,4

We therefore report a case of atrial flutter in which the hearing of “systoles en écho” led to the study of the phonocardiogram and to the discovery that during the long ventricular diastole following carotid sinus stimulation there was a regularly alternating time interval between successive atrial sounds.

Report of Case
A man of 59 years with hypertensive heart disease had had paroxysmal atrial flutter for 5 years before it became the permanent cardiac rhythm. Six months later he developed congestive cardiac failure for the first time. He was treated with digitalis, diuretics, and an antihypertensive drug, but gradually the blood pressure rose again and the nocturnal dyspnea returned.

At the time of admission he was orthopneic, with a blood pressure of 210/150 mm Hg, and he had retinal haemorrhages and signs of congestive cardiac failure. A third heart sound was constantly heard. The pulse rate often varied from moment to moment. An electrocardiogram (ECG) showed atrial flutter, defined according to the criteria of Lewis.5 The degree of A-V block was variable and could easily be increased for a few moments by the stimulation of an unusually sensitive carotid sinus (fig. 1).

Adjustment of the doses of digitalis and diuretics controlled the heart failure, and guanethidine reduced the blood pressure. The patient was discharged with established atrial flutter and a slow ventricular rate.

On auscultation soon after admission, when he had congestive cardiac failure, he was thought to have coupled ventricular ectopic beats. An ECG,
ATRIAL FLUTTER SOUNDS

Figure 1
Electrocardiogram (lead II) showing atrial flutter (A) with changing A-V block (B) with high-grade A-V block following stimulation of the carotid sinus.

Figure 2
Phonocardiogram and electrocardiogram (lead II) during carotid sinus pressure (C.S.P.).
LSE = left sternal edge; MA = mitral area; HF = high frequency; LF = low frequency; AS = atrial sound; 1 = first heart sound; 2 = second heart sound; 3 = third heart sound.

However, showed no extrasystoles. Phonocardiograms were then recorded; these are discussed below. The unusual heart sounds were still audible when there was a high degree of A-V block, even after the heart failure had been relieved, but they were not now so loud and were harder to record.

Phonocardiograms
Phonocardiograms recorded during expiratory apnea showed abnormal heart sounds of two kinds: atrial flutter sounds and other early diastolic sounds. They were both recorded best from the lower left sternal edge.

Atrial Flutter Sounds
The atrial flutter sounds were louder in ventricular diastole than in systole and were not audible clinically. They consisted of two components. The first component was a group of high-pitched vibrations lasting about 0.02 sec and occurring at about the trough of the flutter wave in lead II of the ECG. This was followed by a group of low-frequency vibrations lasting about 0.08 sec and extending, in time, over the summit of the flutter wave in the ECG (fig. 2). They were larger in early diastole than in late diastole. The intervals between atrial sounds al-
Figure 3

Phonocardiogram and electrocardiogram during the long ventricular standstill following carotid sinus pressure. The intervals between successive atrial sounds alternate regularly, the difference being 0.02 sec. F = flutter wave; M = murmur. Other abbreviations same as in figure 1.

Figure 4

Phonocardiogram and electrocardiogram (lead II) showing the various heart sounds and murmurs. X = loud summation sound.
ternated regularly throughout the period of ventricular asystole following carotid sinus pressure, the difference being 0.02 sec (fig. 3).

Other Early Diastolic Sounds

These were the sounds noticed on auscultation. With high degrees of A-V block, two unusual sounds were clearly audible in early ventricular diastole and were conspicuous in the phonocardiogram (fig. 4). The first occurred between the second and third heart sounds. In form it resembled a short soft murmur, and its timing was not precisely that of a flutter sound. The second of these two sounds had the timing and appearance of an unusually loud atrial flutter sound.

These two extra sounds, together with the first, second, and third heart sounds, produced different cadences with different degrees of A-V block (fig. 5). With 2:1 A-V block, a dual rhythm was present (fig. 5A). When 2:1 block alternated with 4:1 block, six sounds were heard in each group, giving an impression of some kind of gallop rhythm (fig. 5B). With 4:1 block there were four sounds, suggesting a normal ventricular systole followed by a premature systole (fig. 5C).

Discussion

In 1893 Huchard⁶ described a patient with complete heart block in whom he heard "two distant and muffled sounds which answered the ordinary heart sounds like a sort of echo." He called these "systoles en écho" and believed that they represented "weak and incomplete systoles." The term is still sometimes used to refer to atrial sounds in complete heart block or atrial flutter.⁷ Van Bogaert⁸ has emphasized that "systoles en écho" can be confused with bigeminy. In our case the two added sounds in early diastole were thought, at first, to be those of coupled ventricular extrasystoles. Inspection of the phonocardiogram later showed that the sounds were the result of two different kinds of atrial sound in atrial flutter with high-grade block.

We cannot agree with Gallavardin,⁹ or Clarac and Pezzi,¹⁰ that the term "systoles en écho" should be reserved for extrasystoles, nor can we agree with its use to describe ordinary atrial sounds. We suggest, however, that it could be used for the situation originally described by Huchard and which we report here, in which atrial sounds mimic coupled extrasystoles.

In atrial flutter two quite distinct kinds of added sound can be heard or recorded: a variable triple and quadruple rhythm¹¹ which

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Figure 5

Phonocardiogram, electrocardiogram, and jugular phlebogram (JVP) in dual rhythm (A), with alternating 2:1 and 4:1 A-V block (B), and with steady 4:1 A-V block (C). The various heart sounds produce various cadences; C shows the two extra sounds mimicking an extrasystole (systole en écho).
Duchosal\textsuperscript{12} attributed to the summation of atrial flutter sounds with ventricular filling sounds, and regular atrial sounds corresponding to the flutter waves in the ECG.

In our case the first of the two sounds in early ventricular diastole was like a short murmur and did not have the timing of a flutter sound. It occurred during the period of rapid filling of the ventricles and is probably, therefore, a murmur associated with ventricular filling, and belongs to the group of summation sounds.\textsuperscript{11} The second of the two sounds was a true atrial flutter sound.

Bennett and Kerr\textsuperscript{13} first heard regular atrial sounds in atrial flutter during the long diastole following carotid sinus pressure. Such sounds have now been recorded 16 times.\textsuperscript{4} They are often described as high-pitched and clicking on ordinary auscultation,\textsuperscript{3,11-16} and Hecht and Myers\textsuperscript{14} have suggested an exocardial origin for them. In our case these sounds were not audible on auscultation, the clinical features which aroused our interest being “systoles en écho” in early diastole. The phonocardiogram, however, showed that true atrial flutter sounds were present and contained two groups of vibrations, the first of which was of high, and the second of low, frequency.

Atrial sounds have been heard or recorded in sinus rhythm,\textsuperscript{17} complete heart block,\textsuperscript{18-20} atrial fibrillation,\textsuperscript{12,21,22} and atrial flutter.\textsuperscript{4} Recordings made from the chest wall, from the esophagus, from the epicardium, and inside the heart cavities have shown that atrial contraction is accompanied by three groups of sound vibrations.\textsuperscript{23-25} Only rarely, however, can three vibrations be identified in the phonocardiogram of man.\textsuperscript{24} More often the atrial sounds are double,\textsuperscript{26-28} but usually only one of these two groups of vibrations can be heard by auscultation.\textsuperscript{17} In a recent study of atrial flutter sounds by intracardiac phonocardiograms, Massumi and associates\textsuperscript{8} have shown that they arise within the right atrium, but whether in the right atrial wall or in the atrioventricular valve is uncertain.\textsuperscript{4} They thus belong to the first of the three groups of atrial sound described by Calo.\textsuperscript{20,23} Atrial flutter sounds may vary in loudness, and occasionally in timing also. Pezzi and Clarac\textsuperscript{29} said that atrial sounds were never heard at the end of diastole in cases of complete heart block, but Duchosal\textsuperscript{27} found the sound sometimes loudest and sometimes softest at the end of diastole. In the patient described by Bennett and Kerr,\textsuperscript{13} flutter sounds alternated in loudness, and Biehl and Simon\textsuperscript{16} found that they were loudest when the patient lay down—a well-known feature of atrial gallop sounds.\textsuperscript{29} In our patient the flutter sounds were loudest in early diastole and were also most easily recorded when he had mild congestive cardiac failure. Hecht and Myers\textsuperscript{14} also noticed this.

The unique feature of our case was the regularly alternating time interval between successive atrial sounds. Neporent\textsuperscript{21} described a case of atrial fibrillation and “impure flutter” in which high-pitched clicking sounds were easily heard and recorded in the phonocardiogram. The atrial sounds showed a definite pattern: “a short interatrial contraction period alternated with a long, and each group showed approximately equal length through most of the tracing.” Neporent’s case differs from ours in two respects: his patient had atrial fibrillation and coarse atrial fibrillation (“impure flutter”), whereas our patient had true atrial flutter, fulfilling the criteria of Lewis\textsuperscript{5}; his patient’s atrial sounds were clicking and clearly audible, whereas our patient’s flutter sounds were not heard on auscultation but only seen in phonocardiograms.

It is reasonable to postulate that the temporal alternation of atrial sounds is associated either with some alternation in atrial excitation or with some alternation in atrial contraction. Atrial muscle contains fibers that have many of the characteristics of specialized conducting tissue grouped into bundles named after Bachmann,\textsuperscript{30} Wenckebach,\textsuperscript{91,92} and Thorell\textsuperscript{33,34} and easily demonstrable in dissected hearts.\textsuperscript{35,36} Moreover, Bachmann’s bundle shows faster conduction than the rest of the atrium,\textsuperscript{37} and its fibers have distinctive transmembrane potentials different from those of ordinary atrial muscle fibers, but similar in some respects to Purkinje fibers.\textsuperscript{38} Vasalle and
Hoffman and Scherfl have shown that when canine atrial muscle fibers have been made inexcitable by a high extracellular concentration of potassium, the activity of the sinus node is still propagated to the coronary sinus and ventricle, presumably by a specialized conducting path between the sinus and atrioventricular nodes.

The nature of the electrical excitation of the atra in atrial flutter is still uncertain. Scherf considered that experimentally induced atrial flutter can be caused by the rapid formation of impulses, whereas the theory of circus movement still requires proof; at this moment there is no definite proof for either mechanism in clinical atrial flutter. On the other hand, Rytand has summarized all the evidence in favor of circus movement and has added fresh evidence suggesting that, when clinical atrial flutter is defined according to the criteria of Lewis, it arises as the result of circus movement.

James has shown how the three internodal tracts (named for Bachmann, Wenckebach, and Thorel) offer the possibility of six different circus movements. He also pointed out that the internodal pathways and the route of an impulse traveling over them resemble a Möbius ring which has its twist at the A-V node. The possible relationship of this topological concept to circus movement is a fascinating one.

In their classic paper on atrial conduction, Eyster and Meck concluded that there might be numerous possible paths offering varying degrees of resistance to the passage of the electrical impulse. James found that the middle internodal tract (Wenckebach's) was usually the least well developed. It is possible that its refractory period might only allow it to accept every second impulse offered to it and thus the excitation might be deflected to another and longer circuit. It seems possible that a circus movement running around the anterior and middle tracts (Bachmann's and Thorel's) and so embracing both venae cavae. If the electrical impulses ran around two such rings alternately, there might be temporal alternation in atrial conduction and in the atrial sounds.

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References

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