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Spontaneous Onset of Type I Atrial Flutter in Patients

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Objectives. This study sought to characterize the spontaneous onset of atrial flutter in patients.

Background. Temporary epicardial electrodes are routinely placed on the atria of patients at the time of open heart surgery and brought out through the anterior chest wall for potential diagnostic and therapeutic use in the postoperative period. We utilized these electrodes to study the spontaneous onset of type I atrial flutter in 16 patients in the postoperative period after open heart surgery.

Methods. Twenty-seven episodes of the spontaneous onset of type I atrial flutter from sinus rhythm were studied in these 16 patients by recording bipolar atrial electrograms simultaneously with at least one electrocardiographic lead during each episode.

Results. In all 27 episodes, the onset of type I atrial flutter was through a transitional rhythm of variable duration (mean 9.3 s) precipitated by a premature atrial beat. In 21 episodes, the transitional rhythm was atrial fibrillation; in 3 episodes it was type II atrial flutter that appeared to generate atrial fibrillation; and in 3 episodes it was a brief (3 to 6 beats), rapid, irregular arrhythmia.

Conclusions. Type I atrial flutter does not start immediately after a premature atrial beat. Rather, it starts after a transitional rhythm that is usually atrial fibrillation. Extrapolating from mapping studies of the onset of atrial flutter in the canine pericarditis model, we suggest that a transitional rhythm is required for the initiation of type I atrial flutter because during that rhythm, the requisites for development of the atrial flutter reentry circuit evolve.

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Although atrial flutter has been recognized for more than eight decades (1), its spontaneous onset in patients has not been described. There have been studies of the onset of induced atrial flutter in the canine sterile pericarditis model (2) that demonstrated that atrial flutter evolves from a preceding transitional rhythm of atrial fibrillation. Also, Watson and Josephson (3) studied the induction of type I (classical) atrial flutter associated with programmed atrial stimulation during electrophysiologic study in 41 patients and showed that a brief period of atrial fibrillation usually preceded the onset of atrial flutter. Although they did not quantitate their data, they stated that, "The immediate appearance of a stable atrial flutter after atrial extrastimuli was uncommon" (3).

After open heart surgery, the electrocardiogram (ECG) is routinely continuously monitored in patients, often simultaneously with bipolar atrial electrograms from temporarily placed epicardial atrial wire electrodes placed at the time of operation for diagnostic purposes. Also, atrial flutter commonly occurs in patients in the immediate period after open heart surgery (4). The routine continuous monitoring of the ECG together with an atrial electrogram in these patients permitted us to characterize the spontaneous onset of atrial flutter to test the hypothesis that type I atrial flutter does not start immediately after a spontaneous premature atrial beat; rather, it evolves from a transitional rhythm (atrial fibrillation) of variable duration.

Methods

Patients. The spontaneous onset of classical (type I) atrial flutter from sinus rhythm was studied during 27 episodes in 16 adult patients. Four patients had undergone valvular surgery, and 12 had undergone saphenous vein coronary artery bypass graft surgery. Five patients had supraventricular arrhythmias preoperatively. Six of the 16 patients were receiving no cardiac medications during the period of observation, and 10 were receiving digoxin simultaneously with either procainamide or quinidine.

At operation, all patients routinely had at least one pair of stainless steel wire electrodes temporarily placed on the right atrial free wall and brought out through the anterior chest wall for possible diagnostic or therapeutic use during the postoperative period (4,5). All patients had routine continuous central monitoring of ECG leads in the immediate period after open heart surgery, and when appropriate, bipolar atrial electrograms from the temporary atrial epicardial electrodes were also monitored continuously. For this study, when the central monitoring technicians saw frequent premature atrial beats in patients who were having episodes of spontaneous

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supraventricular arrhythmia, they simultaneously recorded the patients' ECG and electrogram on frequency modulation (FM) tape for long periods of time. All data were initially recorded on a Honeywell FM tape recorder (model 5600C) for later playback and analysis. The ECGs were recorded between a bandpass of 0.05 and 500 Hz. All bipolar atrial electrograms were recorded between a bandpass of 12 and 500 Hz. Atrial flutter and atrial fibrillation were defined using the criteria of Wells et al. (6,7). The data were subsequently analyzed for episodes in which spontaneous sustained atrial flutter, defined as atrial flutter lasting ≥10 minutes, became manifest. Twenty-seven such episodes were identified in 16 patients. During each onset of type I atrial flutter, one or more ECG leads were recorded simultaneously with a bipolar atrial electrogram from the temporary epicardial right atrial electrodes. In three of the patients, bipolar atrial electrograms were also recorded from temporary epicardial electrodes placed at two additional atrial sites (i.e., a total of three pairs of bipolar atrial electrograms were recorded in these patients).

Results

Summary of data for all episodes. In all 27 episodes, sinus rhythm was interrupted by a spontaneous premature atrial beat that was followed by a transitional rhythm of varying duration before type I (classical) atrial flutter developed. For all episodes of the onset of spontaneous type I atrial flutter, the mean duration of the transitional rhythm was 9.3 s (range ~1 to 60 s). Among the 27 episodes of spontaneous onset of type I atrial flutter, the transitional rhythm was consistent with atrial fibrillation in 21 episodes and with rapid or type II atrial flutter in 3 episodes. However, as is demonstrated later, in the latter episodes, the transitional rhythm probably also was atrial fibrillation. In the remaining three episodes, the premature atrial beat that interrupted sinus rhythm precipitated a rapid but brief (3 to 6 beats) transitional rhythm. In these latter three episodes, because the atrial electrograms recorded during this transitional rhythm were of variable polarity, configuration and cycle length, this transitional rhythm was most consistent with either a short run of atrial fibrillation (7) or atrial repetitive responses (8,9).

Representative examples of atrial fibrillation as a transitional rhythm. Figure 1 illustrates a representative example in which the transitional rhythm was atrial fibrillation. The top trace in Figure 1 is ECG lead II, and the bottom trace is a bipolar atrial electrogram. The asterisk denotes a premature atrial beat that interrupts sinus rhythm. Note that the atrial electrograms following the premature beat vary from beat-to-beat in polarity, configuration and cycle length. The variability of these variables is characteristic of the bipolar atrial electrogram during type I atrial fibrillation (7). The record in Figure 2 is continuous with that recorded in Figure 1. Note that the atrial fibrillation continues until, at the asterisk, the atrial electrogram suddenly develops the characteristics of type I atrial flutter (i.e., uniformity of beat to beat polarity, configuration and cycle length of the recorded atrial electrogram) (6).

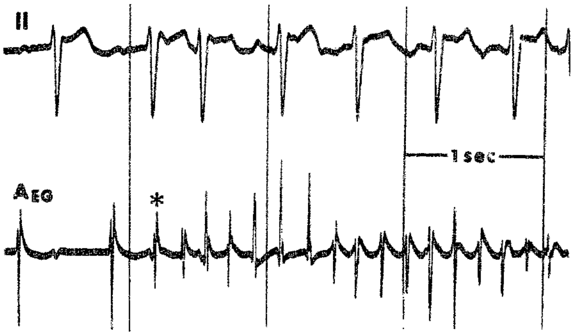
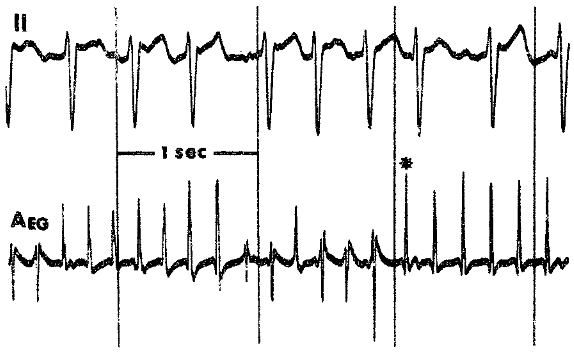


Figure 1. Electrocardiographic lead II recorded simultaneously with a bipolar right atrial electrogram (AEG). **Asterisk** = first premature atrial beat; **time lines** = 1-s intervals. See text for discussion.

The record shown in Figure 3 is continuous with that in Figure 2. Note that the atrial electrograms continue to be characteristic of type I atrial flutter in the presence of 2:1 atrioventricular (AV) conduction.

Another example of the spontaneous onset of atrial flutter with a much longer period of atrial fibrillation as the transitional rhythm before the onset of type I atrial flutter is shown in the continuous recordings in Figures 4 to 6. The top two tracings in Figure 4 are ECG lead II and a bipolar atrial electrogram recorded simultaneously and show that after a premature atrial beat (asterisk) that interrupts sinus rhythm, a rhythm typical of atrial fibrillation is initiated. The bottom atrial electrogram trace in Figure 4 is continuous with the atrial electrogram trace above and with the top trace in Figure 5. All traces in Figure 5 are continuous and show only the bipolar atrial electrograms recorded during this transitional rhythm, which remains classic for atrial fibrillation (7). However, in the top trace in Figure 6, which is continuous with the bottom trace in Figure 5, note that the bipolar atrial electrograms suddenly become quite regular, and in fact display the characteristics of type I atrial flutter (6). The second and third traces in Figure 6 are continuous with the top trace and show the

Figure 2. Electrocardiographic lead II recorded simultaneously with a bipolar right atrial electrogram (AEG). **Traces** are continuous with those in Figures 2 and 3. **Asterisk** = onset of atrial flutter; **time lines** as in Figure 1. See text for discussion.



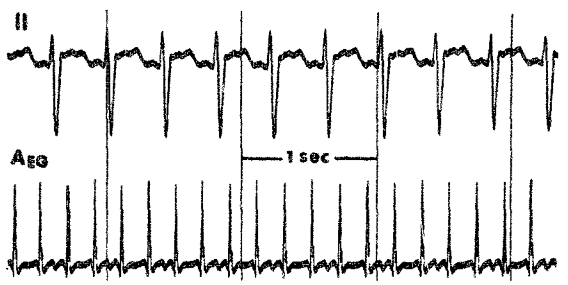


Figure 3. Electrocardiographic lead II recorded simultaneously with a bipolar right atrial electrogram (AEG). **Traces** are continuous with those in Figure 2. **Time lines** = 1-s intervals. See text for discussion.

ECG and bipolar atrial electrogram recorded simultaneously, further demonstrating stable atrial flutter with 2:1 AV conduction.

Representative example of type II atrial flutter as a transitional rhythm. Figures 7 and 8 show a different transition from sinus rhythm to type I atrial flutter. In Figure 7, the top trace is ECG lead II, recorded simultaneously with bipolar atrial electrograms recorded from two atrial sites—the sulcus terminalis (middle trace) and Bachmann's bundle (bottom trace). The asterisk denotes the premature atrial beat that induces the transitional rhythm. Note that in the atrial electrogram recordings, the rhythm that follows the first premature atrial beat clearly differs from atrial fibrillation because the beat to beat polarity, configuration and cycle length of the electrograms are uniform. Note also that the atrial rate is 390 beats/min. This rapid, regular atrial rhythm demonstrates the characteristics of type II atrial flutter (6).

Figure 8 is continuous with the record in Figure 7. Type II atrial flutter persists until, denoted by the asterisk, type I atrial flutter abruptly develops in the middle of the recording. Note that both the cycle length and configuration of the atrial electrograms during type I atrial flutter clearly differ from those during type II atrial flutter.

Of particular interest in Figures 7 and 8, note that during the same period of type II atrial flutter in the two local bipolar electrograms, the ECG is most consistent with, if not diagnostic of, atrial fibrillation. We suggest that this should not be surprising if one considers that the type II atrial flutter at a rate of 390 beats/min is driving the rest of the atria, resulting in atrial fibrillation. Certainly atrial pacing in that rate range will precipitate and maintain atrial fibrillation (5,10,11), so that a spontaneous atrial tachyarrhythmia (type II atrial flutter) occurring in that rate range could also be expected to do the same. Yet another, we suggest less likely, interpretation is that the atria do follow the type II atrial flutter cycle length in a 1:1 manner but that overlapping wavefronts and slight variations in conduction occur, or the rapid type II atrial flutter rate does cause some conduction block and lack of 1:1 atrial activation without necessarily initiating atrial fibrillation; in either case, undulation of the ECG baseline is caused, resembling atrial fibrillation.

Discussion

Onset of reentrant rhythms. The requisites for the initiation of a reentrant rhythm have been well understood for a long time and have been well described. As summarized recently (12), there must be a tissue substrate capable of supporting the reentrant excitation; there must be a central area of block around which the reentrant wave front can circulate; and the initiating excitation wave front must encounter an area of unidirectional block to generate the reentrant excitation. Furthermore, the reentry circuit usually has one or more areas of slow conduction. The best understood and characterized reentrant rhythm has been AV reentrant tachycardia (i.e., AV reentrant excitation associated with the presence of an accessory AV connection). In this latter rhythm, a premature beat initiates the arrhythmia immediately (i.e., there is no preceding transitional rhythm). This occurs because the initiating premature beat encounters unidirectional block at a critical location in the tissue substrate that comprises the reentry circuit. This unidirectional block usually occurs in the accessory AV connection. By a similar mechanism, the premature beat that initiates AV node reentrant tachycardia also initiates the reentrant rhythm immediately. Clearly, as shown in the present study, the same is not true for type I atrial

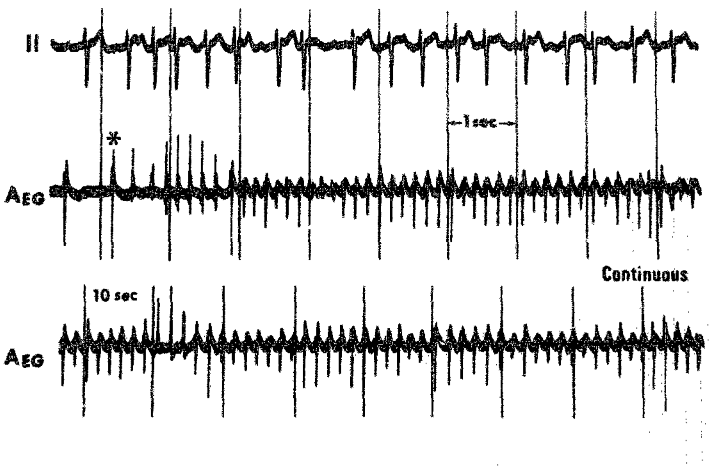


Figure 4. Top two traces show ECG lead II recorded simultaneously with a bipolar right atrial electrogram (AEG). **Bottom trace** is a continuation of the bipolar atrial electrogram without a simultaneously recorded ECG. **Time lines** = 1-s intervals; 10 sec = time from first premature beat (**asterisk**). See text for discussion.

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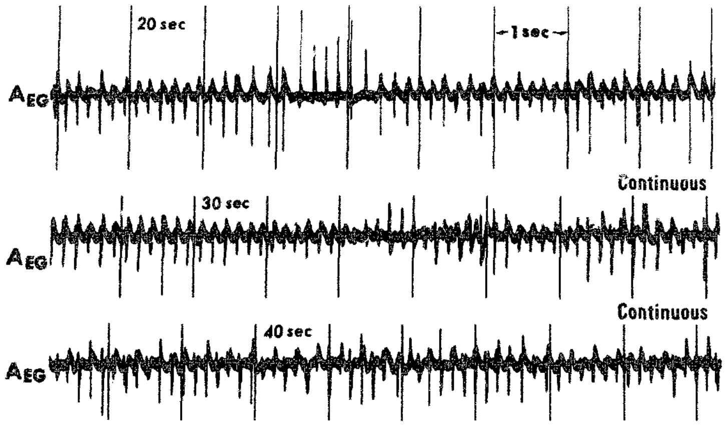

Figure 5. These continuous bipolar right atrial electrogram (AEG) recordings are also continuous with the bottom trace in Figure 4 and the top trace in Figure 6. **Time lines** = 1-s intervals; 20, 30 and 40 sec = duration of arrhythmia from the first premature beat.

flutter, a rhythm now widely recognized as resulting from reentry (12,13).

Onset of type I atrial flutter. The present study demonstrated that, at least in patients after open heart surgery, type I atrial flutter does not start immediately after a premature beat, unlike AV reentrant tachycardia and AV node reentrant tachycardia. Rather, it first goes through a transitional rhythm of atrial fibrillation, the latter sometimes precipitated by type II atrial flutter. As indicated earlier, these observations that transient atrial fibrillation precedes the spontaneous initiation of atrial flutter in patients are consistent with the observations first reported by Watson and Josephson (3) that type I atrial flutter induced in patients during electrophysiologic study generally starts after an initial period of atrial fibrillation.

Insights from studies in animal models. On the basis of simultaneous multisite mapping studies of the onset of atrial flutter in the canine sterile pericarditis model (2), it seems reasonable to suggest that a transitional rhythm is usually necessary for the development of type I atrial flutter in patients because it is during the transitional rhythm that the requisites for initiation of type I atrial flutter (unidirectional block, a central area of block and one or more areas of slow conduction) fully develop. Thus, as in the canine sterile pericarditis model (2), during the induced transitional rhythm, which appears to be atrial fibrillation, a long line of slow conduction first develops. Unidirectional block then occurs in a portion of this line of slow conduction. This permits the unblocked portion of the wave front to circulate around a central area of block, which also develops at this time. This wave front then returns through the area of slow conduction that had previously developed the unidirectional block. This wave front then continues to circulate around the central area of block, generating atrial flutter (2).

The important point is that it is during the transitional rhythm that the requisites for a reentrant rhythm (in this dog model, atrial flutter) developed. There was no anatomic circuit waiting to be engaged by a premature beat or beats. Rather, it was during the period of the transitional atrial fibrillation that there developed an area of slow conduction, unidirectional block and a central line of block around which a reentrant wave front could circulate. Clearly, until the requisites for reentry were fully met, atrial flutter could not occur. We suggest that the same function is probably served by the transitional rhythm that we describe in patients. Furthermore,

Figure 6. Top trace is a bipolar right atrial electrogram (AEG) continuous with that in Figure 5. **Bottom two traces** are ECG lead II and the bipolar atrial electrogram again recorded simultaneously. The atrial electrogram in the **bottom trace** is continuous with that in the **top trace. Time lines** = 1-s intervals; 50 and 60 sec = duration of arrhythmia from the first premature beat. See text for discussion.

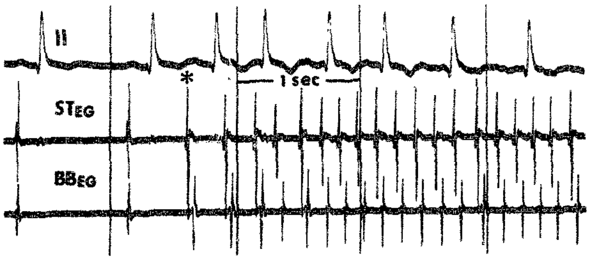

Figure 7. Electrocardiographic lead II **(top trace)** recorded simultaneously with bipolar atrial electrograms from the sulcus terminalis (STEG **[middle trace]**) and Bachmann's bundle (BBEG **[bottom trace]**). **Asterisk** = premature atrial beat that induces the transitional rhythm; **time lines** = 1-s intervals. See text for discussion.

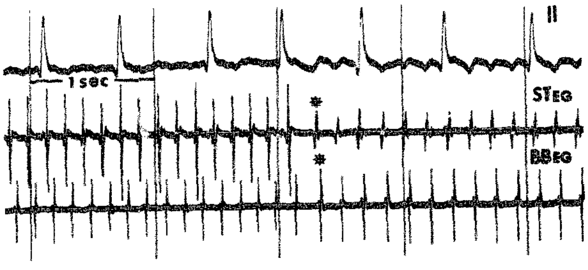

Figure 8. Electrocardiographic lead II **(top trace)** recorded simultaneously with bipolar atrial electrograms from the sulcus terminalis (STEG **[middle trace]**) and Bachmann's bundle (BBEG **[bottom trace]**) continuous with the same tracings as those in Figure 7. **Asterisk** = initiation of type I atrial flutter; **time lines** = 1-s intervals. See text for discussion.

on the basis of the onset of induced atrial flutter during electrophysiologic studies in patients (3), we suggest that this onset is not unique to type I atrial flutter after open heart surgery; rather, it is typical of the onset of type I atrial flutter in general.

Onset of type I atrial flutter through type II atrial flutter. It is of particular interest that in this study, type II atrial flutter was also a transitional rhythm for the development of type I atrial flutter. However, as previously indicated, we suggest that this observation is really only a variation on a theme. Thus, type II atrial flutter is characterized by a very rapid atrial rate, >340 beats/min and usually >360 beats/min (ranging up to 433 beats/min [6]). It is, in effect, "spontaneous rapid atrial pacing." If the rate of type II atrial flutter is so fast that it precipitates atrial fibrillation, it is reasonable to suggest that this atrial fibrillation then simply produces the remaining requisites for development of type I atrial flutter. Support for this notion is present in the data in the present study. As noted in Figures 7 and 8, although the atrial electrograms recorded during the transitional rhythm were characteristic of type II atrial flutter, the ECG was nevertheless characteristic of atrial fibrillation. This observation is consistent with the concept that type II atrial flutter as a transitional rhythm provokes atrial fibrillation because the rest of the atria cannot respond to the very rapid rate generated by the type II atrial flutter in a 1:1 manner. The atrial fibrillation, thus provoked, evolves the additional substrate necessary for the initiation of type I atrial flutter. In contrast, if during type II atrial flutter, the atria follow the type II atrial flutter cycle length in a 1:1 manner but with overlapping wave fronts, or if some conduction block occurs but atrial fibrillation is not provoked, we submit that atrial flutter will not evolve unless during either of the latter two possibilities, the requisites for an atrial flutter reentry circuit evolve. Because either of the latter two interpretations are probably less likely to be causally associated with these requisites developing, we suggest that neither of these latter two possible interpretations is operative.

In short, our interpretation permits one theory to explain the usual onset of type I atrial flutter because even when type II atrial flutter was demonstrated as a prelude to type I atrial flutter, it probably really involved precipitation of atrial fibrillation evolving into classical atrial flutter. Finally, in this regard it may be that reentrant rhythms that are wholly or in significant part functionally determined may almost always require an antecedent rapid transitional rhythm to establish all the requisites for reentry. Thus, it is of interest that some monomorphic ventricular tachycardias have been reported to start either spontaneously (14) or after programmed stimulation (15) with a polymorphic ventricular tachycardia as an antecedent rhythm. More systematic studies of reentrant tachycardias are required to evaluate this concept.

These observations also permit speculation that type II atrial flutter is one of the potential causes of atrial fibrillation. It is conceivable that a focus of type II atrial flutter generates its characteristically rapid rhythm that the rest of the atria are unable to follow in a 1:1 manner. This, then, may precipitate and sustain atrial fibrillation. This certainly has a well described patient model, in that continuous rapid atrial pacing in the rate range of type II atrial flutter can precipitate and sustain atrial fibrillation (4,10,11). Thus, a single focus generating a rapid rhythm at a constant cycle length could generate and sustain atrial fibrillation. As summarized recently (12,13), this is an old notion, now perhaps again resurrected. That this could be a small reentry focus has recently been demonstrated by the work of Schuessler et al. (16).

Summary. We showed that the onset of type I atrial flutter in patients after open heart surgery is caused by a transitional rhythm of variable length. The transitional rhythm is usually, and perhaps always, atrial fibrillation. We suggested, on the basis of studies in an animal model, that it is during the transitional rhythm that critical requisites not already present for the development of atrial flutter evolve. Furthermore, we suggested that when part or all of the reentry circuit is functionally determined, a transitional rhythm may be required before a stable reentrant rhythm can evolve.

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