Development and Validation of Diagnostic Criteria for Atrial Flutter on the Surface Electrocardiogram

Kenneth M. Weinberg, M.D., Pablo Denes, M.D., Alan H. Kadish, M.D., and Jeffrey J. Goldberger, M.D.

From the Department of Medicine and the Feinberg Cardiovascular Institute, Northwestern University, Chicago, IL

Background: There are no universally accepted ECG diagnostic criteria for atrial flutter (AFL), making its differentiation from "coarse" atrial fibrillation (AF) difficult.

Methods: To develop diagnostic criteria for AFL, we examined two sets of ECGs. Set 1 consisted of 100 ECGs (50 AF, AFL) with diagnoses confirmed by intracardiac recordings. Criteria evaluated were presence of F waves in the frontal plane leads, F waves in V₁, sawtooth F waves, rate, and regularity of ventricular response. Set 2 included 200 ECGs taken from the hospital database each of which had already been interpreted by a cardiologist as either AF (n = 100) or AFL (n = 100). Set 2 was blindly read by electrophysiologists whose consensus-diagnoses were compared to the diagnoses made by using the best criteria identified from the Set 1 data.

Results: The criteria of frontal plane F waves, regular or partially regular ventricular response, and their combination had sensitivities of 92%, 98%, and 90% and specificities of 100%, 78%, and 100% in Set 1 for the diagnosis of AFL. In Set 2, concordance of electrophysiologist and cardiologist diagnoses was only 84%. The criteria of frontal plane F waves, regular or partially regular ventricular response, and their combination resulted in concordances with the cardiologist diagnoses of 85%, 85%, and 82% and with the electrophysiologist-consensus diagnoses of 90%, 89%, and 94% (P < 0.001).

Conclusions: The criteria of frontal plane F waves and regular or partially regular ventricular response aid in the proper diagnosis of AFL. Because management strategies may differ for AF and AFL, it is important to adopt a more rigorous diagnostic approach.

Ann Noninvasive Electrocardiol 2008;13(2):145–154

atrial flutter; atrial fibrillation; electrocardiogram

Atrial flutter (AFL) is the second most common atrial tachyarrhythmia after atrial fibrillation (AF), with an estimated 200,000 new cases in the United States annually.¹ Several studies^{2–4} have noted diagnostic issues related to AF and flutter. Specifically, in some cases, differentiation of AFL from AF on the surface ECG can be challenging and controversial. Knight et al.³ sent a questionnaire containing three ECGs to 176 physicians with different levels of expertise, from internal medicine house officers to attending cardiologists. The two ECGs designated AF were individually read correctly by only 31% and 79% of physicians. The ECG designated AFL was correctly identified by only 87%. Of note, the study provoked a letter to the editor⁵ disputing the diagnosis of AF on one of the ECGs. The distinction between AFL and AF is more important

than ever today as the primary treatment strategies for AFL and AF may differ.

While the characteristic sawtooth pattern of typical AFL is well recognized, other types of AFL may appear on the electrocardiogram. ECG textbooks^{6–9} do not provide any well-defined set of diagnostic criteria for AFL on the surface ECG. Hence, the presence of coarse or large fibrillatory waves in AF could make differentiation of this rhythm from AFL difficult. This study was therefore undertaken to develop diagnostic criteria to aid in the proper differentiation of AFL from AF.

METHODS

This study was approved by the Northwestern University Institutional Review Board. The aims of

Address for reprints: Jeffrey J. Goldberger, M.D., Northwestern Memorial Hospital, 251 East Huron Street Feinberg 8-542, Chicago, IL 60611. Fax: 312-926-2707; E-mail: j-goldberger@northwestern.edu

©2008, Copyright the Authors
Journal compilation ©2008, Blackwell Publishing, Inc.

this study were 1) to develop simple criteria that could improve the diagnostic accuracy for AF and AFL using ECGs with diagnoses confirmed by intracardiac recordings, typically obtained from patients referred for catheter ablation and 2) to apply the criteria to an unselected group of ECGs interpreted by cardiologists and electrophysiologists to evaluate for concordance.

Developing Criteria for the Diagnosis of AFL

For the purpose of deriving the diagnostic criteria, 100 ECGs with diagnoses confirmed by invasive electrophysiologic testing (Set 1) were obtained. Fifty ECGs with the diagnosis of AF and 50 with the diagnosis of AFL were selected from consecutive patients who had undergone electrophysiologic testing and who had both right atrial and left atrial (or coronary sinus) recordings to confirm the ECG diagnosis. AF was recognized by variably irregular atrial activity in both atria while AFL was defined as a macro-reentrant tachyarrhythmia with regular atrial activity in both atria. Regularity was defined by consistent electrogram morphology and minimal cycle length variability (<10 ms). From digitally stored (sampling rate 1000 Hz) electrophysiologic study recordings, 10 cycle lengths of atrial activity were measured using electronic calipers from both the right atrium and the left atrium (or coronary sinus). Intraindividual cycle length variability was measured as the standard deviation of the 10 cycles recorded in each chamber.

The following findings were examined as potential diagnostic ECG criteria for the presence of AFL:

1. Presence of flutter waves in lead V₁.
2. Presence of flutter waves in any of the frontal plane leads.
For either case, to be classified as flutter waves, the atrial activity was required to have a constant rate, amplitude, and morphology.
3. Presence of a typical "sawtooth pattern" in the inferior leads, with a gradual downward slope followed by an abrupt upward inscription.
4. Cycle length of any apparent atrial activity.
5. Regularity of the ventricular response. This was classified as variably irregular (also commonly known as irregularly irregular), completely regular, or partially regular. This latter category included grouped beating (a repeating Wencke-

bach pattern) (see Fig. 1) and/or periods of alternating levels of atrioventricular block (e.g., 2:1 to 4:1).

These criteria were applied to Set 1, and sensitivity and specificity for the diagnosis of AFL were determined for each of the criteria and their combinations.

Applying the Criteria to an Unselected Sample of ECGs

From the above analysis, the criteria with the highest sensitivity for the diagnosis of AFL were then applied to a second set of 200 ECGs (Set 2), which were obtained from the Marquette Muse database at Northwestern Memorial Hospital. A preliminary interpretation of these ECGs, including a rhythm diagnosis, is supplied by the computer; the ECGs are then overread by cardiologists who assign a final diagnosis, which is stored in the database. ECGs were selected so as to find 100 each of the cardiologist-confirmed diagnoses of AF and AFL. Over the period reviewed from the database, 6.4% of ECGs were diagnosed as AF and 1% were diagnosed as AFL. Because the presence of paced rhythms or premature ventricular complexes might affect the ability to classify the regularity of the ventricular response, ECGs with these attributes were excluded from analysis. Consequently, 232 ECGs were screened to find 200 acceptable ECGs.

All ECGs in Set 2 were read blindly (blind to the cardiologist's diagnosis) by two cardiac electrophysiologists who were unaware of the results from Set 1. In cases of disagreement (31 cases) between the two readers, a third electrophysiologist read the ECG, and a consensus diagnosis was then agreed to by all. These ECGs were then interpreted using the criteria defined in Set 1. The original cardiologist and the electrophysiologist-consensus diagnoses were then evaluated for concordance with the diagnoses determined by the criteria.

Statistical Analysis

For continuous variables, mean and standard deviations were calculated and expressed in appropriate units. Student's *t*-test was used to compare means for continuous variables. A *P* value <0.05 was considered significant.

Figure 1. ECG tracings (lead II) from three patients with atrial flutter, demonstrating grouped beating, or a partially regular ventricular response. The top tracing shows groups of two QRS complexes. The middle tracing shows groups of three and groups of two QRS complexes. The bottom tracing shows groups of 2, 3, and 4 QRS complexes.

RESULTS

Developing Criteria for the Diagnosis of AFL

These subjects had an average age of 59 ± 15 years and 77% were males. All of the subjects with AFL and 70% of the subjects with AF had been referred for catheter ablation. In subjects with AFL, the average cycle length was 253 ± 27 ms for the right atrium and 254 ± 27 ms for the left atrium. Cycle length variability was 1.4 ± 0.8 ms in the right atrium and 1.4 ± 0.8 ms in the left atrium. In subjects with AF, the average cycle length was 171 ± 42 ms in the right atrium and 171 ± 47 ms in the left atrium (both $P < 0.001$ vs AFL). Cycle length variability was 18.8 ± 10.0 ms in the right atrium and 17.9 ± 11.3 ms in the left atrium (both $P < 0.001$ vs AFL). Of the 50 ECGs with AFL, intracardiac mapping revealed that 43 were counterclockwise cavotricuspid isthmus dependent, 5 were clockwise isthmus dependent, and 2 were nonisthmus dependent.

Of the 50 ECGs with AFL, 39 (78%) had F waves in V_1 , 46 (92%) had F waves in the frontal plane, and 39 (78%) had F waves in both. A sawtooth pattern was observed in only 39 (78%). There was a completely regular ventricular response in 22 (44%), a partially regular ventricular response in 27 (54%), and a variably irregular ventricular response in 1 (2%). Of the 50 ECGs with AF, 7 (14%) had apparent F waves in V_1 and none had apparent F waves in the frontal plane. There was a completely regular response in none, a partially regular ventricular response in 11 (22%), and a variably irregular response in 39 (78%). Figure 2 shows examples of ECGs with AF that have apparent F waves in V_1 or a partially regular ventricular response. Figure 3 shows an example of an ECG with apparent F waves in the frontal plane and a variably irregular ventricular response; intracardiac recordings confirm the diagnosis of AF characterized by varying left and right atrial electrogram morphology and rate.

The sensitivity and specificity of each of the criteria for the diagnosis of AFL and their combinations are shown in Table 1. The criterion of a regular or

Figure 2. Twelve-lead ECGs from Set 1 of atrial fibrillation. Panel A demonstrates an ECG with apparent F waves in lead V₁ with a variably irregular ventricular response. Panel B demonstrates a partially regular ventricular response but no F waves in either V₁ or the frontal plane leads.

partially regular ventricular response had a sensitivity of 98% and a specificity of 78%. Using the criterion of F waves in any frontal plane lead, the sensitivity was 92% and the specificity was 100%. Using the combination of a regular or partially regular ventricular response plus the presence of an F wave in the frontal plane, the sensitivity was 90% with a specificity of 100%.

Applying the Criteria to an Unselected Sample of ECGs

Of the 200 ECGs in Set 2, one was removed from further analysis due to a technically poor tracing. The subjects whose ECGs were included in Set 2 had an average age of 68 ± 14 years and 60% were males.

Figure 3. Panel A: 12-lead ECG of atrial fibrillation with apparent flutter waves in the frontal plane leads but a variably irregular ventricular response. Panel B: Intracardiac recordings from the same patient as panel A. Surface leads I, II, and V₁, and intracardiac recordings from the high right atrium (HRA), His bundle electrogram (HIS), and proximal (CSp) and distal (CSd) coronary sinus (left atrium) are shown. While the surface leads demonstrate apparent flutter waves, the cycle lengths and electrogram morphology in the right atrium and left atrium are variable. The average cycle length in the right atrium was 185 ± 11.5 ms and in the left atrium was 189 ± 11.2 ms.

ECG Set 2 was also examined for the presence of the above criteria. The ventricular response was determined to be regular in 32 (16%) ECGs, partially regular in 55 (28%), and variably irregular in 112 (56%). F waves were identified in V₁ in 88 (44%) cases, in any frontal plane lead in 80 (40%), and in both in 74 (37%). "Sawtooth" pattern was identified

in 42 (21%). Apparent atrial activity was seen in 84 (42%) of the ECGs with an average cycle length of 220 ± 35 ms.

The electrophysiologist-consensus diagnoses were compared to the original cardiologist diagnoses. Of the 100 ECGs diagnosed as AF by cardiologists, the electrophysiologists reclassified

Table 1. Sensitivity and Specificity of Criteria for the Diagnosis of Atrial Flutter in Set 1 (Rhythm Diagnoses Confirmed by Intracardiac Recordings)

	Sensitivity (%)	Specificity (%)
F waves in V ₁	78	86
F waves in any frontal plane lead	92	100
Sawtooth F waves	78	100
Atrial rate less than 350 bpm	90	82
Regular or partially regular ventricular response	98	78
F waves in both V ₁ and frontal plane	78	100
Regular or partially regular ventricular response PLUS F waves in both V ₁ and any frontal plane lead	76	100
F waves in V ₁	76	100
F waves in any frontal plane lead	90	100

only one as AFL. Of the 99 ECGs diagnosed as AFL by cardiologists, the electrophysiologists reclassified 30 as AF. The concordance between the cardiologist and electrophysiologist diagnoses was only 84%.

ECG Set 2 was then reclassified according to each of the three criteria with the highest sensitivity for the diagnosis of AFL as derived from Set 1. If AFL is diagnosed by the simple rule of an F wave in the frontal plane, 119 ECGs were designated AF

and 80 as AFL. The electrophysiologist-consensus diagnosis agreed with the criteria diagnosis in 114 of 119 (96%) ECGs showing AF and 66 of 80 (82%) ECGs with AFL for a total concordance of 90%. The original cardiologist diagnosis agreed with the criteria diagnosis in 94 of 119 (79%) ECGs showing AF and 75 of 80 (94%) ECGs with AFL for a total concordance of 85%.

If AFL is diagnosed by a regular or partially regular ventricular response, 112 ECGs were designated AF and 87 as AFL. The electrophysiologist-consensus diagnosis agreed with the criteria diagnosis in 109 of 112 (97%) ECGs showing AF and 68 of 87 (78%) ECGs with AFL for a total concordance of 89%. The original cardiologist diagnosis agreed with the criteria diagnosis in 91 of 112 (81%) ECGs showing AF and 79 of 87 (91%) ECGs with AFL for a total concordance of 85%.

If AFL is diagnosed by the combination of F waves in the frontal plane and a regular or partially regular ventricular response, 131 ECGs were designated as AF and 68 as AFL. Figure 4 shows the distribution of these criteria in the ECGs of Set 2. The electrophysiologist-consensus diagnosis agreed with the criteria diagnosis in 123 of 131 (94%) ECGs showing AF and 63 of 68 (93%) ECGs with AFL for a total concordance of 94%. The original cardiologist diagnosis agreed with the criteria diagnosis in 97 of 131 (74%) ECGs showing AF and 66 of 68 (97%) ECGs with AFL for a total concordance of 82%. The concordance between the criteria-based

Figure 4. The distribution of the criteria in the ECGs in Set 2.

Figure 5. Twelve-lead ECGs of atrial flutter (by electrophysiologist diagnosis). Panel A: The ventricular response is regular but F waves are not clearly seen in the frontal plane. Based on the criteria, a diagnosis of a atrial flutter would not be made. Panel B: The ventricular response is variably irregular and F waves are apparent in the frontal plane. Based on the criteria, a diagnosis of atrial flutter would not be made.

diagnoses and the electrophysiologist-consensus diagnoses was significantly greater ($P < 0.001$) than the concordance with the cardiologists diagnoses. Figure 5 shows examples of ECGs in which the criteria did not suggest the diagnosis of AFL while the electrophysiologists (and cardiologists) diagnosed as AFL.

DISCUSSION

This study highlights the diagnostic problems that may occur in differentiating AF from AFL and presents a practical solution. In an unselected sample of 200 ECGs from the hospital database, the electrophysiologist-consensus diagnosis differed

from the cardiologist diagnosis in 16%. While the source of the error may be debated, it is clear that the reliance on pure visual inspection of the ECG, rather than specific criteria, leads to discordance in interpretation. We have developed and tested simple criteria that can be applied to reliably aid in the diagnosis of AFL on the surface ECG. The use of these criteria resulted in a 94% concordance with the electrophysiologist-consensus diagnosis. Given the high sensitivity and specificity in the ECGs with diagnoses confirmed by intracardiac recordings and the high correlation with the electrophysiologist-consensus diagnoses in a large unselected set of ECGs, the optimal criteria for the diagnosis of AFL are the combination of a regular or partially regular ventricular response plus the presence of an F wave in the frontal plane. As there are currently no standard criteria in the literature and as there are clear discrepancies, even among experts, in the visual discrimination between AFL and AF, we propose these criteria be adopted as diagnostic aids that have high sensitivity and specificity in the differentiation of these rhythms. As the treatment approaches for AFL may differ from that for AF, it is important to properly differentiate these rhythms.

With the advent of intracardiac mapping studies, the pathophysiologies of AF and AFL have been better defined. The chaotic appearance of AF is due to multiple reentrant circuits colliding and reconstituting throughout the atria.¹⁰ Alternatively, rapidly firing foci such as those in the pulmonary veins,¹¹ may have variable breakthroughs into the atria giving the appearance of fibrillation. In most cases, AFL is caused by a single reentrant circuit with boundaries including the tricuspid annulus, crista terminalis, inferior vena cava, Eustachian ridge, and the coronary sinus; these are said to be isthmus dependent.¹² This relatively unvarying circuit leads to a constant rate of 250–350 beats per minute. Counterclockwise activation of this pathway leads to negative F waves in the inferior leads and positive F waves in lead V₁, while clockwise activation results in positive F waves in the inferior leads and negative F waves in lead V₁. Other types of AFL may use only part or none of this pathway, but are nevertheless considered to represent a single macro-reentrant circuit in the atria. As with any single reentrant circuit in either the atria or the ventricle, the repetitive activation of the chamber results in a monomorphic arrhythmia. Thus, a repetitive F wave is a hallmark of AFL. Our study

identifies the limb leads as the best location to identify these F waves.

Most descriptions of AFL point out that the ventricular response is regular, often 2:1, but it can be any ratio or varying ratios. AFL may produce a regular ventricular response due to the regularity of the atrial input (low standard deviation in cycle length) to the AV node and a fixed AV ratio conduction block. Regularly irregular ventricular responses can occur in AFL when there are changing ratios of conduction block or when multiple levels of block exist in the conduction system.¹³ As ECGs may be presented in multiple formats, a format that provides a rhythm strip should be used to adequately assess the conduction pattern. Although uncommon, a variably irregular ventricular response may occur in AFL with multiple levels of block and/or changes in autonomic input. The irregularity of the ventricular response in AF is likely due to the irregular atrial input to the AV node (high standard deviation in cycle length) as well as multiple levels of block. Krummen et al.⁴ evaluated the diagnostic accuracy of “irregularly irregular” RR intervals in separating AF from AFL. They analyzed the periodicity of the RR interval by evaluating ratios of the RR intervals to the shortest observed RR interval and observing the percentage of RR intervals that were one of a number of set multiples of the shortest RR intervals. They noted that RR interval periodicity separated typical AFL from fibrillation reasonably well, but not atypical AFL. Of note, the presence of grouped beating (a partially regular response) is not necessarily the same as calculating a single number representing RR interval periodicity. The perception of grouped beating requires an analysis of the order and structure of the RR intervals, as well. Figure 1 shows examples of grouped beating where the periodicity may not be high due to the variability in the intergroup intervals.

Based on Krummen et al.⁴ and this study, it is clear that a regular ventricular response in AFL is often not observed. However, at least in our study, only a minority (3%) of ECGs with AFL had a variably irregular ventricular response (see Fig. 5, Panel B). It is possible this was higher in Krummen et al.⁴ but no specific data were presented aside from the overall percent RR interval periodicity. In this study, the combination of a regular or partially regular response thus accounts for 97% of ECGs with AFL in Set 1 and 96% of the ECGs diagnosed by the electrophysiologist-consensus as AFL. While AFL may be diagnosed with a variably irregular

ventricular response (Fig. 5, Panel B), careful review by the reader should be undertaken. Qualifiers such as "possible" or "probable" AFL may also be used to indicate the rare ECGs that do not meet all the criteria but still have features highly suggestive of AFL.

Limitations

Although there are only two rules to follow with the proposed criteria, applying them in certain cases may be difficult and subjective. F wave morphology needs to be constant, but this can be difficult to verify. Particularly at faster ventricular rates, the F waves are often altered or completely hidden by the QRS or T waves (Fig. 2, Panel B). However, at fast rates, any diagnostic criteria or visual assessment will be hampered by the inability to visualize the F waves.

While Set 2 did not have diagnoses confirmed by electrophysiologic recordings, the criteria performed exceptionally well in this set of ECGs with a 94% concordance with the electrophysiologist-consensus diagnosis. As it is not feasible to perform electrophysiology studies on an unselected group of consecutive patients with diagnoses of AFL and AF, the electrophysiologist-consensus diagnosis provides a reasonable standard. Two of the eight ECGs in which the electrophysiologists diagnosed AFL but the criteria did not suggest AFL are shown in Figure 5. In Figure 5, Panel A, the physicians diagnosed AFL based on the suggestion of flutter waves in lead III and the rate and regularity of the rhythm. In Figure 5, Panel B, the physicians diagnosed AFL due to the very characteristic F waves in the frontal plane leads, despite the variably irregular ventricular response.

While in Set 1, the single criterion of F waves in the frontal planes had as high a sensitivity and specificity as the two criteria, it should be noted that the Set 1 ECGs may have been "easier" to interpret than those in Set 2 as most of these patients were referred for catheter ablation of the diagnosed rhythm.

Differentiation of AFL and atrial tachycardia using these criteria is not possible. Atrial tachycardia would also be expected to have distinct and unchanging atrial activity. Typically, atrial tachycardia is diagnosed when the atrial rate is less than 240 per minute and when there is an isoelectric baseline between atrial deflections.¹⁴ However, there is significant overlap in the rates of these rhythms, an

isoelectric baseline may be observed in AFL, and ultimately invasive studies are needed to provide a definitive diagnosis. In addition, these criteria may not apply to ECG patterns in patients who have had surgical or catheter ablation for atrial fibrillation due to the extensive scarring that may be noted. Finally, while the proposed criteria are helpful in providing a more rigorous framework to diagnose AF and AFL, each ECG should be evaluated carefully by a trained individual who can identify other clues on a particular ECG that might suggest an alternative diagnosis.

Implications

Differentiating AFL from AF is more important than ever today as treatment strategies for these arrhythmias may differ. In persons above 50 years, the incidence of AFL has been estimated to be 317/100,000 person-years.¹ Therefore, given our maturing population, AFL will become an increasingly common disorder seen in both primary care and cardiologist offices. AFL, as a macro-reentrant circuit located in the right atrium, can be cured with a high chance of success and a low complication rate by radiofrequency catheter ablation.^{15,16} Catheter ablation is often chosen as first-line therapy, particularly since this appears to be preferable to medical therapy with higher success rates, improved quality of life, lower occurrence of AF, and less need for rehospitalization at follow-up.¹⁷ While catheter-based therapeutic techniques for AF are gaining in popularity, especially for paroxysmal forms caused by ectopic tachycardias originating from the pulmonary veins, their success and complication rates are not as favorable as those for AFL.¹⁸ Indeed, catheter ablation is not first-line therapy for treatment of AF. In addition, publication of the AFFIRM¹⁹ and RACE²⁰ trials may lead to increased use of the rate-control strategy in patients with AF. While there are no studies comparing catheter ablation for AFL with a rate-control strategy, given the high success rate of catheter ablation and its low morbidity, it seems likely that this could be a superior approach to rate control in these patients. Therefore, correctly differentiating these rhythms can have important therapeutic consequences.

Current rhythm differentiation between AF and AFL is done by visual inspection. It has been well documented that this frequently may result in different diagnoses, as shown by our evaluation and

that of Knight et al.³ Applying our criteria to the ECGs of Knight et al.,³ the diagnosis was concordant with the authors' diagnoses in all three cases. It is clear that the proposed criteria provide an important new diagnostic aid in differentiating AFL and AF.

Acknowledgment: *We thank Sri Sundaram, M.D., for his insightful demonstration of the need for diagnostic criteria for AFL.*

REFERENCES

- Granada J, Uribe W, Chyou PH, et al. Incidence and predictors of atrial flutter in the general population. *J Am Coll Cardiol* 2000;36:2242-2246.
- Bogun F, Anh D, Kalahasty G, et al. Misdiagnosis of atrial fibrillation and its clinical consequences. *Am J Med* 2004;117:636-642.
- Knight BP, Michaud GF, Strickberger SA, et al. Electrocardiographic differentiation of atrial flutter from atrial fibrillation by physicians. *J Electrocardiol* 1999;32:315-319.
- Krummen DE, Feld GK, Narayan SM. Diagnostic accuracy of irregularly irregular RR intervals in separating atrial fibrillation from atrial flutter. *Am J Cardiol* 2006;98:209-214.
- Rautaharju PM. Differentiation of atrial flutter from atrial fibrillation. *J Electrocardiol* 2000;33:203.
- Rankin A, Rae A. Sinus and atrial arrhythmias. In: MacFarlane PLT, (ed.): *Comprehensive Electrocardiology: Theory and Practice in Health and Disease*. New York, Pergamon Press, 1989, pp.881-914.
- Chou T, Knilans T. *Electrocardiography in Clinical Practice: Adult and Pediatric*. Philadelphia, W.B. Saunders, 1996.
- Chung E. *Electrocardiography: Practical Applications with Vectorial Principles*. New York, Appleton-Century-Crofts, 1985.
- Wagner G. *Marriott's Practical Electrocardiography*. 10th Edition. Philadelphia, Lippincott Williams & Williams, 2001.
- Rubart M, Zipes D. Genesis of cardiac arrhythmias: Electrophysiological considerations. In: Braunwald EZD, Libby P (eds.): *Heart Disease: A Textbook of Cardiovascular Medicine*. Philadelphia, W.B. Saunders, 2001;659-699.
- Haissaguerre M, Jais P, Shah DC, et al. Spontaneous initiation of atrial fibrillation by ectopic beats originating in the pulmonary veins. *N Engl J Med* 1998;339:659-666.
- Josephson M. *Clinical Cardiac Electrophysiology*. Philadelphia, Lippincott Williams & Williams, 2002.
- Amat y Leon F, Chuquimia R, Wu D, et al. Alternating Wenckebach periodicity: A common electrophysiologic response. *Am J Cardiol* 1975;36:757-764.
- Saoudi N, Cosio F, Waldo A, et al. A classification of atrial flutter and regular atrial tachycardia according to electrophysiological mechanisms and anatomical bases: A Statement from a Joint Expert Group from The Working Group of Arrhythmias of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. *Eur Heart J* 2001;22:1162-1182.
- Poty H, Saoudi N, Nair M, et al. Radiofrequency catheter ablation of atrial flutter. Further insights into the various types of isthmus block: Application to ablation during sinus rhythm. *Circulation* 1996;94:3204-3213.
- Tai CT, Chen SA, Chiang CE, et al. Long-term outcome of radiofrequency catheter ablation for typical atrial flutter: Risk prediction of recurrent arrhythmias. *J Cardiovasc Electrophysiol* 1998;9:115-121.
- Natale A, Newby KH, Pisano E, et al. Prospective randomized comparison of antiarrhythmic therapy versus first-line radiofrequency ablation in patients with atrial flutter. *J Am Coll Cardiol* 2000;35:1898-1904.
- Padanilam BJ, Prystowsky EN. Should atrial fibrillation ablation be considered first-line therapy for some patients? Should ablation be first-line therapy and for whom? The antagonist position. *Circulation* 2005;112:1223-1229: discussion 1230.
- Wyse DG, Waldo AL, DiMarco JP, et al. A comparison of rate control and rhythm control in patients with atrial fibrillation. *N Engl J Med* 2002;347:1825-1833.
- Van Gelder IC, Hagens VE, Bosker HA, et al. A comparison of rate control and rhythm control in patients with recurrent persistent atrial fibrillation. *N Engl J Med* 2002;347:1834-1840.