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Clinical Investigations

Atrial Fibrillation Independently Prolongs Hospital Stay after Coronary Artery Bypass Surgery

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Summary

Background: Atrial fibrillation (AF) is the most common arrhythmia occurring in patients after coronary artery bypass surgery (CABG).

Hypothesis: The purpose of this study was to determine whether AF independently prolonged postoperative length of stay (LOS).

Methods: Consecutive patients undergoing elective CABG were identified. Baseline clinical variables, postoperative course including the development of AF, and postoperative LOS were recorded.

Results: In all, 216 patients (aged 61 ± 13 years) were examined. Postoperative LOS was 11.3 ± 6.4 days (median LOS = 9 days). Fifty-five patients (25%) developed AF. Among 16 variables examined, the univariate predictors of LOS included age ($p < 0.001$), preoperative left ventricular ejection fraction ($p < 0.001$), absence of a prior smoking history ($p < 0.05$), bypass limited to venous conduits ($p < 0.001$), postoperative AF ($p < 0.001$), and the occurrence of a postoperative event ($p < 0.001$). Length of stay for patients who developed AF was significantly longer than that for patients who did not (15.1 ± 9.0 vs. 10.0 ± 4.6 days, $p < 0.001$). After adjusting for other significant variables, the occurrence of AF after CABG independently prolonged LOS: patients who developed AF stayed 3.2 ± 1.7 days longer than patients who did not ($p < 0.001$).

Conclusions: Atrial fibrillation lengthens hospital stay after CABG, and its effect is independent of other important variables. Identification of patients who are at risk for AF and successful treatment to prevent AF will likely contribute to major reductions in consumption of health care resources in patients with CABG.

Key words: atrial fibrillation, coronary artery bypass surgery, length of stay

Introduction

During this era of widespread health care reform aimed at cost containment, physicians and third-party payers have begun to focus on cardiac surgery, which is a major contributor to health care expenditures. Approximately 500,000 patients undergo coronary artery bypass surgery (CABG) each year,[1] at an estimated cost of $45,000 per procedure.[2] Because of the high expenditures for cardiac surgery, efforts have been made to decrease the cost of surgery while maintaining appropriate postoperative care. Hospital length of stay (LOS), in particular, is an important determinant of total hospital costs from cardiac surgery. Changes, including same-day admissions, and clinical pathways aimed at early extubation and early transfer out of the intensive care unit, have resulted in a shorter LOS without any adverse effects on morbidity or mortality.[3–8]

Atrial fibrillation (AF) is the most common arrhythmia seen after cardiac surgery occurring in 25 to 40% of patients.[9–15] Although AF is often short lived and without sequelae, it can result in increased morbidity and also in increased hospital costs due to the need for more intensive monitoring, additional medications, and more extensive diagnostic and therapeutic interventions. Several earlier trials have demonstrated that AF can adversely affect hospital LOS after CABG,[11, 14–17] but few have demonstrated the unique contribution of AF to hospital LOS in the presence of other confounding variables.[15, 16] The purposes of this study were to determine whether AF independently prolonged hospital LOS after CABG, and to determine which additional factors, if any, contributed to a prolonged postoperative stay.

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Methods

Patient Eligibility

In a prospective study designed to examine the risk factors for AF, consecutive patients undergoing elective cardiac surgery at St. Luke's Hospital over a 2-year period extending from February 1992 to February 1994 were identified. Patients without a history of AF who were in normal sinus rhythm on preoperative electrocardiogram (ECG) were included in the study. Patients requiring class I or III antiarrhythmic agents were excluded from participation. The results of this investigation have been reported previously.[18] In the current analysis, only those patients referred for cardiac surgery limited exclusively to CABG are included.

Inpatient Follow-Up

Baseline clinical variables and postoperative course were recorded. Patients were monitored by telemetry in the intensive care unit, or "step-down" unit for several days after surgery. Telemetry monitoring was discontinued at the discretion of the primary cardiologist. Any episode of AF lasting longer than 30 min was recorded. Atrial fibrillation was defined by the absence of P waves and the presence of fibrillatory waves in the isoelectric portion of the ECG or telemetry strip. After discharge, the medical record data of all patients were reviewed to determine postoperative LOS and to document the occurrence of any significant postoperative event. A postoperative event was predefined as an event that was expected to delay discharge and was included in the analysis so that adjustments could be made for a prolonged postoperative LOS resulting from factors unrelated to the variables studied (e.g., unforseen complications). These consisted of the following: a significant postoperative infection (pneumonia, wound infection, bacteremia), a significant neurologic event (cerebral vascular accident, seizures, psychosis), respiratory failure requiring prolonged mechanical ventilation, peripheral or pulmonary emboli, acute renal failure, ventricular arrhythmias or high-grade atrioventricular block, repeat surgery, and wound disruption.

Statistical Analysis

Statistical analyses were performed using SPSS (Statistical Package for the Social Sciences). The mean postoperative LOS (± standard deviation) was calculated for each discrete clinical variable. For better visualization of the effect that continuous variables had on hospital LOS, we incorporated certain predefined cut-off values for these variables so that they might also be compared as discrete variables. Student's *t*-tests were used to measure differences in LOS in the presence or absence of each discrete variable and Pearson's Product-Moment correlations were used to determine the contribution to LOS for continuous variables. Simultaneous partial regression analysis was performed on all significant variables to determine each variable's unique contribution to LOS.

Results

Baseline Clinical Variables and Hospital Course

In all, 216 patients (aged 61 ± 13 years, 72% men) were enrolled in the study. The baseline clinical characteristics of these patients and the intra- and postoperative variables are outlined in Table I. Of these, 37% had a prior myocardial infarction. The average left ventricular ejection fraction was 49 ± 15%. The surgical mortality was 2.3%.

Forty-four patients (20%) experienced a postoperative event. Among these patients, 17 had a postoperative infection, 11 experienced a neurologic event, 11 had respiratory failure, 6 had peripheral or pulmonary emboli, 1 had acute renal failure, 21 had ventricular arrhythmias or significant atrioventricular block, 1 underwent repeat surgery, and 4 had wound disruption. Since some patients experienced more than one postoperative event, the number of events are greater than the number of patients with events.

Fifty five patients (25%) developed AF after CABG. Atrial fibrillation occurred 4.1 ± 3.0 days after surgery. The duration of AF varied from < 1 h to several days. Figure 1 depicts the number of patients who developed AF on each postoperative day. This arrhythmia tended to occur early after surgery with the majority of patients (73%) developing AF by the third postoperative day.

TABLE I Clinical characteristics of the study population

Baseline variables	N (%)
Age (years) (± standard of the mean)	61 ± 13
Male sex (%)	156 (72)
Diabetes (%)	71 (33)
Hypertension (%)	123 (57)
Smoking history (%)	127 (59)
Lung disease (%)	19 (9)
Prior MI (%)	79 (37)
NYHA angina class III or IV (%)	179 (83)
Ejection fraction (%) (± standard of the mean)	49 ± 15%
LVH on ECG (%)	10 (5)
Intraoperative data	
Aortic cross clamp time (min) (± standard of the mean)	46 ± 42
Number of vessels bypassed (± standard of the mean)	3.1 ± 1.0
Bypass with ≥ 1 IMA (%)	177 (83)
Postoperative course	
Beta blockers (%)	81 (38)
Significant event (%)[a]	44 (20)
AF (%)	55 (25)
Mortality (%)	5 (2.3)

[a] See Methods for definition.

Abbreviations: AF = atrial fibrillation, ECG = electrocardiogram, IMA = internal mammary artery, LVH = left ventricular hypertrophy, MI = myocardial infarction, NYHA = New York Heart Association.

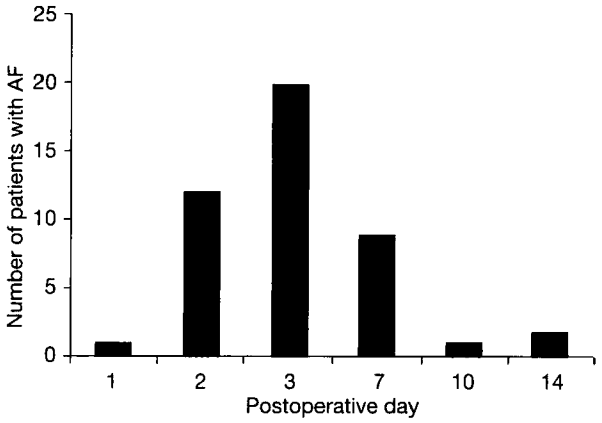

FIG. 1 The incidence of atrial fibrillation (AF) following coronary artery bypass grafting as a function of postoperative day. The majority of patients (73%) developed AF by the third postoperative day.

TABLE II Univariate analysis of variables as a function of postoperative length of stay

Clinical variable	Number of patients	Length of stay	p Value
Age ≤ 65 years	135	9.8 ± 4.0	<0.001
Age > 65 years	81	13.9 ± 8.6	
Male	156	11.1 ± 6.0	NS
Female	60	12.0 ± 7.4	
Diabetes	71	12.0 ± 6.8	NS
No diabetes	145	11.0 ± 6.2	
Hypertension	93	11.3 ± 5.8	NS
No hypertension	123	11.4 ± 7.2	
Smoking history	127	10.3 ± 4.8	<0.05
No smoking history	89	12.7 ± 8.0	
Lung disease	19	12.9 ± 8.5	NS
No lung disease	196	11.2 ± 6.2	
Prior MI	79	11.7 ± 6.7	NS
No prior MI	136	11.1 ± 6.2	
NYHA angina class I or II	36	10.7 ± 5.0	NS
NYHA angina class III or IV	179	11.5 ± 6.7	
Ejection fraction > 40%	148	10.1 ± 4.8	<0.001
Ejection fraction ≤ 40%	68	13.8 ± 8.4	
LVH on ECG	10	13.0 ± 6.5	NS
No LVH on ECG	205	11.2 ± 6.4	
Aortic cross clamp > 75 min	31	12.3 ± 8.5	NS
Aortic cross clamp ≤ 75 min	169	10.8 ± 5.6	
1 or 2 vessels bypassed	49	13.3 ± 9.3	NS
> 2 vessels bypassed	167	10.5 ± 5.2	
Bypass with IMA	177	10.6 ± 5.4	<0.001
Bypass without IMA	37	15.0 ± 9.2	
Beta blockers	81	13.0 ± 6.5	NS
No beta blockers	135	11.8 ± 6.9	
Significant event [a]	44	17.5 ± 10.0	<0.001
No significant event	172	9.7 ± 3.7	
AF	55	15.2 ± 9.0	<0.001
No AF	161	10.0 ± 4.6	

[a] See Methods for details.
Abbreviations as in Table I.

Length of Stay

The mean postoperative LOS was 11.3 ± 6.4 days; the median stay was 9 days. The LOS in the presence or absence of each clinical variable is depicted in Table II. Partial regression analysis resulted in five clinical variables that independently prolonged postoperative LOS (Table III). These variables included the following: age, ejection fraction, the occurrence of a major complication, bypass limited to saphenous vein grafts, and the occurrence of postoperative AF. Even after accounting for all other confounding variables, patients who developed AF after CABG had an LOS that was 3.2 ± 1.6 days longer than patients who did not [95% confidence interval (CI) 1.53, 4.78, p < 0.001) (Fig. 2)].

Discussion

Relationship of Postoperative Atrial Fibrillation to Length of Stay

Rising health care costs have influenced our approach to the treatment of the patient post CABG. Recently the health care system has begun to focus on hospital LOS, a significant contributor to hospital expenditures. Our study demonstrated that

TABLE III Independent predictors of prolonged postoperative length of stay

Factor	Coefficient	p Value
Age	2.63	<0.001
Ejection fraction	−2.09	<0.01
Bypass with IMA	−3.15	<0.001
Significant event [a]	5.65	<0.001
AF	3.16	<0.001

[a] See Methods for details.
Abbreviations as in Table I.

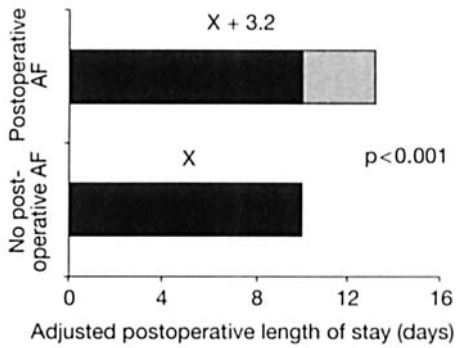

FIG. 2 Relative length of stay in the presence or absence of atrial fibrillation (AF). Patients who developed AF were hospitalized more than 3 days longer than patients who were free of this arrhythmia, even after accounting for differences in other baseline variables. x = relative length of stay for patients without AF.

AF prolonged LOS after CABG, and this effect was independent of other confounding variables. In our study, AF was common, occurring in one of four patients and resulting in an LOS prolongation of several days. At our institution, each additional hospital day in the cardiac step-down unit contributes approximately $1,500 to the total cost of hospitalization per cardiac surgery patient. Of an estimated 500,000 patients referred for CABG each year in the United States, approximately 125,000 patients may develop AF, requiring on average 3 additional days in the hospital. Assuming that hospital costs in our institution are typical for costs nationwide, then the development of AF confers an additional $562 million dollars to total health care expenditures each year. Since AF is a modifiable variable, a decrease in the incidence of postoperative AF, or changes in the management of AF, may decrease hospital LOS and result in a decreased utilization of hospital resources.

Earlier research focusing on the interaction of AF and hospital LOS after cardiac surgery is limited. Several investigators have reported that AF can delay discharge,[11, 14–17, 19] although only two demonstrated an independent effect of AF on postoperative LOS:[15, 16] in a recent study of 2,035 patients referred for CABG,[16] multiple pre-, intra-, and postoperative variables were examined to determine which contributed to a postoperative LOS over 14 days. Multivariate analysis demonstrated that the presence of a supraventricular arrhythmia significantly increased the likelihood of an extended hospitalization [relative risk (RR) for LOS > 14 days for AF patients compared with patients free of this arrhythmia: 1.23, 95% CI 1.11, 1.37, $p < 0.0001$]. In another study examining 570 consecutive patients undergoing CABG,[15] the development of AF was also shown to prolong LOS after surgery (15.3 ± 28.6 vs. 9.3 ± 19.6, $p = 0.001$). These investigators reported a 4.9-day longer adjusted hospital LOS for patients who developed AF compared with patients who remained in sinus rhythm. The variability in LOS reported in this study was quite large as depicted by the excessive standard deviation in length of stay, however, the results do agree closely with the current study.

Cresswell *et al.*[11] and Mathew *et al.*[17] both examined large cohorts of patients undergoing cardiac surgery and demonstrated that the occurrence of AF was a univariate predictor for a prolonged postoperative LOS. In these reports, AF was associated with a higher incidence of other pre- and postoperative factors known to affect hospital LOS. Since postoperative LOS was not adjusted for these confounding variables, the unique contribution of AF to hospital LOS was uncertain. Lazar *et al.*[5] and Weintraub *et al.*[20] reported that a postoperative arrhythmia independently lengthened hospital LOS. These findings, however, were not specific for patients with AF, as their definition of a postoperative arrhythmia also included bradyarrhythmias and ventricular tachyarrhythmias.

Prevention of Postoperative Atrial Fibrillation

Of all the variables we examined, AF is the only potentially modifiable variable that prolongs hospital LOS after CABG: age and left ventricular ejection fraction are both fixed variables that cannot be modified. Attempts to prevent postoperative complications, including practices of early extubation and ambulation, as well as careful attention to sterile techniques are already widely exercised by all healthcare workers and likely cannot be significantly improved upon. The use of arterial conduits, when possible, is also universally implemented since mammary grafts clearly offer a mortality benefit.[21] However, efforts to prevent the occurrence of AF are not universal and often are unsuccessful.

Beta blockers are the most effective therapy used to prevent AF after cardiac surgery. Several earlier studies[10, 22] have suggested that withdrawal of beta-adrenergic blockade contributed to the occurrence of atrial arrhythmias seen after cardiac surgery, while other studies have shown a benefit to prophylactic treatment of AF with beta blockers.[9, 10, 19, 22–27] Despite their apparent benefit, beta blockers may be underused or may be started too late in the postoperative period. In the current study, the use of beta-blocking agents in the postoperative period had no effect on postoperative LOS. This likely reflects the low rate of utilization of this valuable antiarrhythmic drug in the cohort studied (< 40% of patients were treated with beta blockers after surgery).

In a promising study by Daoud *et al.*,[28] 124 patients referred for CABG were randomized to treatment with amiodarone or placebo. The administration of amiodarone resulted in a nearly 50% reduction in the incidence of AF after CABG (23 vs. 42%, $p = 0.03$). It was interesting to note that patients assigned to amiodarone were discharged earlier than those randomized to placebo, and the authors reported a significant reduction in hospital costs ($18,375 ± $13,863 vs. $26,491 ± $23,837, $p = 0.03$). These findings imply a potential improvement in postoperative LOS and cost savings by preventing AF. Since only hospital charges were examined, the preoperative (outpatient) costs of amiodarone therapy were not included in the analysis and may have had substantial impact on total patient charges related to surgery. Further research is indicated to determine whether effective treatment to prevent AF will translate into earlier discharge home as well as overall cost efficacy.

Study Limitations

Since telemetry monitoring was discontinued at the discretion of the primary cardiologist, many patients were not monitored through hospital discharge. Although it is possible that some episodes of AF were not recorded, we feel that the majority of episodes were documented, because sustained AF is often accompanied by clinical symptoms, or by findings on physical examination.

We used medical record data to identify the occurrence of a significant postoperative event and the hospital discharge date. This information was obtained by an investigator who was blinded to other patient data, hence it is unlikely that collection of data in this manner substantially biased the results of this study.

We were unable to conclude successfully why AF adversely affected hospital stay since we did not thoroughly examine the many variables involved in the way AF was controlled or

treated. Since the occurrence of AF in our study was not associated with an increase in postoperative events (including stroke), we postulate that in general the additional time spent in the hospital was a result of an increased need for cardiac monitoring and treatment prior to and after cardioversion, and/or initiating anticoagulation.

We acknowledge that the mean postoperative LOS obtained in our study was longer than the expected postoperative LOS for patients undergoing bypass surgery in 1999 because the study was completed more than 5 years ago. Nonetheless we suspect that AF remains a major impediment to reductions in LOS across the spectrum of CABG patients as exemplified by our study and other recent results.[15, 16]

Conclusion

We conclude that AF was the only observed potentially modifiable variable that affected postoperative LOS after CABG. Since efforts to prevent this arrhythmia are often unsuccessful, more effective therapy is required to lessen the burden of this stubborn postoperative complication. Successful prophylaxis of this arrhythmia will likely lead to a meaningful shortening of post-CABG LOS and a decrease in hospital costs.

References

1. National Center for Health Statistics: Health Resources Utilization Branch—1994
2. Metropolitan Life Insurance Company, Statistical Bulletin—1997; 78:20–27
3. Krohn BG, Kay JH, Mendez MA, Zubiate P, Kay GL: Rapid sustained recovery after cardiac operations. *J Thorac Cardiovasc Surg* 1990;100:194–197
4. Anderson RP, Guyton SW, Paull DL, Tidwell SL: Selection of patients for same day coronary bypass operations. *J Thorac Cardiovasc Surg* 1993;105:444–452
5. Lazar HL, Fitzgerald C, Gross S, Heeren T, Aldea GS, Shermin RJ: Determinants of length of stay after coronary artery bypass graft surgery. *Circulation* 1995;92(suppl II):II-20–24
6. Loop FD, Christiansen EK, Lester JL, Cosgrove DM, Franco I, Golding LR: A strategy for cost containment in coronary surgery. *J Am Med Assoc* 1983;250:63–66
7. Loop FD, Higgins TL, Panda R, Pearce G, Estafanous FG: Myocardial protection during cardiac operations: Decreased morbidity and lower cost with blood cardioplegia and coronary sinus perfusion. *J Thorac Cardiovasc Surg* 1992;104:608–618
8. Engelman RM, Rousou JA, Flack JE III, Deaton DW, Humphrey CB, Ellison LH, Allmendinger PD, Owen SG, Pekow PS: Fast track recovery of the coronary bypass patient. *Ann Thorac Surg* 1994;58:1742–1746
9. Stephenson LW, MacVaugh H, Tomasello DN, Josephson ME: Propranolol for prevention of postoperative cardiac arrhythmias: A randomized study. *Ann Thorac Surg* 1980;29:113–116
10. Mohr R, Smolinsky A, Goor DA: Prevention of supraventricular tachyarrhythmia with low-dose propranolol after coronary bypass. *J Thorac Cardiovasc Surg* 1981;81:840–845
11. Creswell LL, Schuessler RB, Rosenbloom M, Cox JL: Hazards of postoperative atrial arrhythmias. *Ann Thorac Surg* 1993;56: 539–549
12. Hashimoto K, Ilstrup DM, Schaff HV: Influence of clinical and hemodynamic variables on risk of supraventricular tachycardia after coronary artery bypass. *J Thorac Cardiovasc Surg* 1991;101: 56–65
13. Hutchinson LA, Steinberg JS: A prospective study of atrial fibrillation after cardiac surgery: Multivariate risk analysis using P wave signal-averaged ECG and clinical variables. *A.N.E.* 1996;1: 133–140
14. Angelini P, Feldman MI, Lufschanowski R, Leachman RD: Cardiac arrhythmias during and after heart surgery: Diagnosis and management. *Prog Cardiovasc Dis* 1974;16:469–495
15. Aranki SF, Shaw DP, Adams DH, Rizzo RJ, Couper GS, VanderVliet M, Collins JJ, Cohn LH, Burstin HR: Predictors of atrial fibrillation after coronary artery surgery. Current trends and impact on hospital resources. *Circulation* 1996;94:390–397
16. Herlitz J, Brandrup G, Emanuelsson H, Haglid M, Karlsson T, Karlson BW, Sandén W: Determinants of time to discharge following coronary artery bypass grafting. *Eur J Cardiothorac Surg* 1997;11:533–538
17. Mathew JP, Parks R, Savino JS, Friedman AS, Koch C, Mangano DT, Browner WS: Atrial fibrillation following coronary artery bypass graft surgery; predictors, outcomes and resource utilization. *J Am Med Assoc* 1996;276:300–306
18. Steinberg JS, Zelenkofske S, Wong SC, Gelernt M, Sciacca R, Menchavez E: Value of the P-wave signal averaged ECG for predicting atrial fibrillation after cardiac surgery. *Circulation* 1993; 88:2618–2622
19. Rubin DA, Nieminski KE, Reed GE, Herman MV: Predictors, prevention, and long term prognosis of atrial fibrillation after coronary artery bypass graft operations. *J Thorac Cardiovasc Surg* 1987;94: 331–335
20. Weintraub WS, Jones EL, Craver J, Guyton R, Cohen C: Determinants of prolonged length of hospital stay after coronary bypass surgery. *Circulation* 1989;80:276–284
21. Cameron AAC, Green GE, Brogno DA, Thornton J: Internal thoracic artery grafts: 20-year clinical follow-up. *J Am Coll Cardiol* 1995;25:188–192
22. Salazar C, Frishman W, Friedman S, Patel J, Lin YT, Oka Y, Frater RW, Becker RM: Beta-blockade therapy for supraventricular tachyarrhythmias after coronary surgery: A propanolol withdrawal syndrome? *Angiology* 1979;30:816–819
23. Suttorp MJ, Kingma JH, Peels HO, Koomen EM, Tijssen JG, van Hemel NM, Defauw JA, Ernst SM: Effectiveness of sotalol in preventing supraventricular tachyarrhythmias shortly after coronary artery bypass grafting. *Am J Cardiol* 1991;68:1163–1169
24. Roffman JA, Fieldman A: Digoxin and propranolol in the prophylaxis of supraventricular tachydysrhythmias after coronary artery bypass surgery. *Ann Thorac Surg* 1981;31:496–501
25. Kowey PR, Taylor JE, Rials SJ, Marinchak RA: Meta-analysis of the effectiveness of prophylactic drug therapy in preventing supraventricular arrhythmia early after coronary artery bypass grafting. *Am J Cardiol* 1992;69:963–965
26. Mills SA, Poole GV Jr, Breyer RH, Holliday RH, Lavender SW II, Blanton KR, Hudspeth AS, Johnston FR, Cordell AR: Digoxin and propranolol in the prophylaxis of dysrhythmias after coronary artery bypass grafting. *Circulation* 1983;68(suppl II):II-222–224
27. Daudon P, Corcos T, Gandjbakhch I, Levasseur JP, Cabrol A, Cabrol C: Prevention of atrial fibrillation or flutter by acebutolol after coronary bypass grafting. *Am J Cardiol* 1986;58:933–936
28. Daoud EG, Strickberger SA, Man KC, Goyal R, Deeb GM, Bolling SF, Pagani FD, Bitar C, Meissner MD, Morady F: Preoperative amiodarone as prophylaxis against atrial fibrillation after heart surgery. *N Engl J Med* 1997;337:1785–1791