ORIGINAL ARTICLE

Determinants of Postoperative Atrial Fibrillation and Associated Resource Utilization in Cardiac Surgery

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Introduction and objectives. Atrial arrhythmias occur after cardiac surgery in 10-65% of patients. The most common postoperative arrhythmia is atrial fibrillation (AF).

Methods. The Tehran Heart Center Cardiovascular Research database (of 15 580 patients) was used to identify all patients who developed any form of AF as a postoperative complication following their first cardiac surgery (e.g. for coronary artery bypass grafting [CABG], valve surgery or both), with and without cardiopulmonary bypass, between June 2002 and March 2008.

Results. Of the 15 580 patients who underwent a first cardiac surgery, 11 435 (73.4%) were male and their mean age was 58.16±10.11 years. New-onset AF developed postoperatively in 1129 (7.2%). New-onset AF occurred most frequently in patients who were aged ≥60 years and who had no history of beta-blocker use. In addition, patients were more likely to develop new-onset AF if they had valve surgery alone (16.5%) or CABG plus valve surgery combined (9.6%), needed intra-aortic balloon counterpulsation (IABC), or had a long cardiopulmonary bypass time. Multivariate analysis identified the following predictors of postoperative AF: older age, history of renal failure, congestive heart disease, operation type, longer perfusion time, and use of IABC. The incidence of early readmission (4.4%) was significantly higher in patients with postoperative AF, as was the duration of hospitalization, both overall and postoperatively. The short-term postoperative mortality rate was 3.8%.

Conclusions. Atrial fibrillation frequently develops after cardiac surgery and is associated not only with increased morbidity and mortality, but also with increased use of health-care resources.

Key words: *Atrial fibrillation. Coronary artery bypass. Heart valves.*

Factores determinantes de fibrilación auricular postoperatoria y el uso de recursos en cirugía cardiaca

Introducción y objetivos. Las arritmias auriculares tras cirugía cardiaca se dan en un 10-65% de los pacientes. La fibrilación auricular (FA) es la arritmia más frecuente tras la cirugía cardiaca.

Métodos. Se utilizó la base de datos para investigación cardiovascular del Tehran Heart Center (15.580 pacientes) para identificar a todos los pacientes que presentaron algún tipo de FA como complicación postoperatoria tras su primera intervención de cirugía cardiaca (*bypass* arterial coronario, cirugía valvular o *bypass* más cirugía valvular) con o sin *bypass* cardiopulmonar (BCP), entre junio de 2002 y marzo de 2008.

Resultados. De los 15.580 pacientes a los que se practicó una primera operación de cirugía cardiaca, 11.435 (73,4%) eran varones con una media de edad de 58,16 ± 10,11 años. Se produjo una FA postoperatoria de nueva aparición en 1.129 (7,2%) de estos pacientes. La FA de nueva aparición fue más frecuente en los pacientes de edad ≥ 60 años que no tenían antecedentes de tratamiento con bloqueadores beta. Los pacientes con una FA de nueva aparición tenían también mayor probabilidad de que se les hubiera practicado una operación de cirugía valvular (16,5%) o de *bypass* más cirugía valvular (9,6%), así como de necesidad de balón de contrapulsación intraaórtico (BCIA) y un tiempo de *bypass* cardiopulmonar mayor. Los factores predictivos de la aparición de FA postoperatoria en el análisis multivariable fueron la mayor edad, los antecedentes de insuficiencia renal, la insuficiencia cardiaca congestiva, el tipo de operación, el mayor tiempo de perfusión y el uso de BCIA. En los pacientes con FA postoperatoria hubo una incidencia significativamente superior de reingresos tempranos (4,4%), así como una duración de la hospitalización (DdH) y una DdH postoperatoria más prolongadas. La tasa de mortalidad postoperatoria temprana fue del 3,8%.

Conclusiones. La aparición de FA es frecuente tras la cirugía cardiaca y se asocia no sólo a un aumento de la morbimortalidad, sino también a un incremento de la utilización de recursos.

Palabras clave: *Fibrilación auricular. Bypass arterial coronario. Válvulas cardiacas.*

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ABBREVIATIONS

AF: atrial fibrillation
CABG: coronary artery bypass graft
OR: odds ratio
IABC: intra-aortic balloon counterpulsation

INTRODUCTION

Atrial arrhythmias post cardiac surgery occur in 10% to 65% of patients based on patient description, method of arrhythmia observation, type of surgery, and definition of arrhythmia.[1] The most common complication and arrhythmia after cardiac surgery is atrial fibrillation (AF). Postoperative AF after coronary artery bypass graft (CABG) occurs in approximately 25%-40% of patients and 50%-60% after valvular surgery.[2,3] Postoperative AF adversely affects the surgical mortality and morbidity and consequently leads to a longer hospital stay, more resources utilization, and increases the cost of care.[4] The current study was conducted to determine the incidence of postoperative new-onset AF in patients undergoing a variety of open cardiac surgery procedures and identify preoperative, and perioperative factors which have significant association with the development of postoperative new-onset AF. We also compare resource utilization hospital length of stay (HLOS), post operation length of stay (PLOS) in coronary care unit (CCU)/intensive care unit (ICU) and readmission (re-hospitalization with or without reoperation) between patients with and without AF.

METHODS

Between June 2002 and March 2008 Tehran Heart Center (THC) Cardiovascular Research database was used retrospectively to identify all patients who developed any new-onset AF as a postoperative complication following their first cardiac surgery bypass (CPB). We excluded some patients based on the following criteria: *a)* history of prior CABG or valve or CABG + valve surgery; *b)* history of any type of arrhythmia before operation. Postoperative new-onset AF was defined by the documentation of AF rhythm with at least 5 minute duration within 96 hours at postoperative period. AF was defined as absent *P* wave before the QRS complex together with irregular ventricular rhythm on the rhythm strips. In asymptomatic patients AF rhythms were assessed not only on the basis of a rhythm strips recording but also with ECG monitoring and finally analyzed by an anesthesiologist. Other patients may experience palpitations, breathlessness, chest pain, excessive sweating, or hypotension; in these patients AF rhythm was confirmed by 12-lead ECG besides anesthesiologist's interpretation. All patients were monitored daily until discharge with continuous ECG monitoring. Our treatment protocol for postoperative AF included: replacement of potassium and magnesium or pharmacologic cardioversion with amiodarone, initiated intraoperatively (150 mg intravenously) and continued postoperatively until discharge (200 mg orally 3 times daily). Control of the ventricular response is the most effective therapy. Various agents have been used for this purpose, but the most effective are digoxin, calcium channel blockers, beta blockers and amiodarone, which were used sometimes in our patients. Anticoagulation was administered if patient had one of these criteria: large left atrial size (>4.5 cm), valvular heart disease, congestive cardiac failure, age >75 years with AF and diabetes, previous cerebrovascular accident (CVA)/ transient ischemic attack (TIA), or hypertension, unless hemorrhagic risks are presumed unacceptably high. Preoperative and operative risk factors and resource utilization parameters were analyzed for their association with postoperative new-onset AF.

Statistical Methods

Numerical variables were presented as mean (SD), while categorical variables were summarized by absolute frequencies and percentages. Continuous variables were compared using the Student *t* test or nonparametric Mann-Whitney *U* test whenever the data did not appear to have normal distributions, and categorical variables were compared using χ^2 test. Multivariable stepwise logistic regression model for risk factors predicting postoperation new-onset atrial fibrillation was constructed. Multivariable analysis was also done to evaluate the effect of post operative AF on in-hospital mortality and resource utilization. Multivariable linear regression models for comparing HLOS and PLOS across the two groups of patients in presence of confounders were also established and the associations were presented with 95% CIs. Variables were included in the multivariable model if the *P* value was found to be ≤.15 in the univariate analysis. The associations of independent predictors with AF in

the final model were expressed as odds ratios (OR) with 95% CIs. Model discrimination was measured using the c statistic, which is equal to the area under the ROC (receiver operating characteristic) curve. Model calibration was estimated using the Hosmer-Lemeshow (HL) goodness-of-fit statistic (higher *P* values imply that the model fit the observed data better). For the statistical analysis, the statistical software SPSS version 13.0 for windows (SPSS Inc., Chicago, IL) and the statistical package SAS version 9.1 for windows (SAS Institute Inc., Cary, NC, USA) were used. All *P* values were 2-tailed, with statistical significance defined by $P \leq .05$.

RESULTS

Of the 15 580 patients undergoing first cardiac surgery 11 435 (73.4%) were males and 4145 (26.6%) females, and average age was 58.16 (10.11) years. Postoperative new onset AF occurred in 1129 (7.2%) of patients. Baseline patient characteristics, preoperative and operative risk factors are presented in Table 1. New developed AF was more frequent in patient's ≥60 years old. Positive history of cerebrovascular accident, beta-blocker consumption, renal failure (RF), congestive heart failure (CHF) was more prevalent in patients with AF than those without. Patients with new-onset AF were also more likely to have valve (16.5%), and CABG + valve (9.6%) surgery, and need intra aortic balloon pump (IABP) insertion and longer CPB times. New-onset patients were less likely to be smokers, hypercholesterolemic, and have positive family history. There were also significant differences in both artery and vein graft use between the 2 groups (both $P<.001$). Multivariable predictors for the occurrence of postoperative AF were age (51-60 years, OR=1.862; ≥60 years, OR=2.749; $P<.0001$), history of renal failure (OR=1.651; $P=.0131$), congestive heart failure (OR=1.681; $P<.0001$), operation type (valve surgery, OR=5.648; CABG + valve surgery, OR=2.432; $P<.0001$), perfusion time (OR=1.006; $P<.0001$), and IABP insertion (OR=1.825; $P<.0001$) (Table 2). Preoperative beta-blocker use has a protective effect on postoperative new onset AF (OR=0.71, $P<.001$). In-hospital outcomes are presented in Table 3. Patients with postoperative AF had significantly higher incidence of early readmission (4.4%), longer HLOS and PLOS. The mortality rate during 30 days admission in patients with and without new-onset postoperative AF was 3.8% vs 0.7% ($P<.001$), respectively. AF was strongly associated with mortality, readmission rate, PLOS and HLOS after adjusting for confounding effects of age, BMI, gender, dyslipidemia, number of diseased vessels, preoperative renal failure, diabetes, hypertension, CVA, peripheral vascular disease (PVD), CHF, smoking, family history, MI, left main disease, operation status, and IABP insertion. These results are shown in Table 4 and 5.

DISCUSSION

The incidence of AF in general population is approximately 1.8%.[5] In general surgical procedures, the incidence of AF is approximately 5%.[6,7] In hospitalized patients, AF occurs in between 8% and 14% of patients.[8] For patients undergoing open cardiac procedures, the occurrence of AF is clearly much higher, with incidence ranging from 3.1% to 91%, and the reported median around 30%.[9-17] We demonstrated the incidence rate of 7.2% for postoperative new-onset AF in our study. This low rate may be related to low mean age (58.16 ±10.11) in our study group or may be related to exclusion of patients with history of atrial arrhythmias and exclusion of patients with second surgical procedures.

Several factors are associated with the development of AF after cardiac surgery. These factors can be classified as preoperative, intraoperative, or postoperative. Table 2 shows the age, history of renal failure and history of congestive heart failure as preoperative factors associated with an increased incidence of AF after cardiac surgery. One of the consistently predictors of higher incidence of postoperative AF is older age.[18-20] This can be explained by the age-related structural changes in the atrium such as dilatation, muscle atrophy, decreased conduction tissue, and fibrosis.[21] History of congestive heart failure is also a predictor of postoperative atrial arrhythmia. Our study showed CHF as predictive for postoperation AF. Heart failure may cause atrial fibrillation, with neurohumoral activation and electromechanical feedback playing an important mediating role[22]. We also demonstrated renal failure as a predictor of postoperative AF. Mechanisms that have been proposed for this event in these patients include ischemia, atheroembolism, and systemic inflammation.[23,24] We also found that AF occurs more frequently in patients who underwent valve surgery or CABG + valve surgery compared to CABG surgery alone. The incidence of AF after valve surgery typically exceeds in patients undergoing coronary revascularization alone. This may be resulted from structural and hemodynamic abnormalities such as left atrial enlargement, pathological changes from rheumatic heart disease, increased left atrial pressure, and surgical trauma.[25] Our study showed longer perfusion time as a predictor of postoperative AF. Cardiopulmonary bypass is associated with an ischemia-reperfusion injury, inducing a complex

TABLE 1. **Preoperative and Operative Variables According to New-Onset Atrial Fibrillation (AF) Post Cardiac Surgery**

Characteristics	Total	AF	No-AF	*P*
Preoperative risk factors				
Gender				<.001
Male	11435/15580 (73.4)	763/1129 (67.6)	10672/14451 (73.8)	
Female	4145/15580 (26.6)	366/1129 (32.4)	3779/14451 (26.2)	
Age, y				<.001
≤50	3550/15580 (22.8)	158/1129 (14)	3392/14451 (23.5)	
51-60	5228/15580 (33.6)	314/1129 (27.8)	4914/14451 (34.0)	
>60	6799/15580 (43.6)	657/1129 (58.1)	6145/14451 (42.5)	
BMI, mean (SD), kg/m²	27.09 (4.03)	26.86 (4.3)	27.10 (4)	.074
Smoke	5919/15519 (38.1)	362/1121 (32.3)	759/1121 (67.7)	<.001
Diabetes	4735/15579 (30.4)	329/1129 (29.1)	4406/14450 (30.5)	.342
Dyslipidemia	10034/15573 (64.4)	642/1128 (56.9)	9392/14445 (65.0)	<.001
Family history	5582/15439 (36.2)	344/1114 (30.9)	5238/14325 (36.6)	<.001
Hypertension	7915/15579 (50.8)	592/1129 (52.4)	7323/14450 (50.7)	.255
CVA	983/15575 (6.3)	88/1128 (7.8)	895/14447 (6.2)	.033
PVD	262/15567 (1.7)	24/1128 (2.1)	238/14439 (1.6)	.228
Renal failure	270/15579 (1.7)	34/1128 (3)	236/14451 (1.6)	.001
Chronic lung disease (severe)	14/15568 (0.1)	3/1128 (0.3)	11/14440 (0.1)	.076
Immunosuppressive therapy	271/15575 (1.7)	25/1128 (2.2)	246/14447 (1.7)	.204
Beta-blocker consumption	12890/15431 (83.5)	889/1122 (79.2)	12001/14309 (83.9)	<.001
MI	5814/15571 (37.3)	380/1128 (33.7)	5434/14443 (37.6)	.008
CHF	2156/15578 (13.8)	322/1129 (28.5)	1834/14449 (12.7)	<.001
Angina	14926/15576 (95.8)	1036/1128 (91.8)	13890/14448 (96.1)	<.001
CCS>3	909/14270 (6.4)	74/1015 (7.3)	835/13255 (6.3)	.213
Number of diseased vessels >2	10609/15532 (68.3)	695/1124 (61.8)	9914/14408 (68.8)	<.001
Left main disease ≥50%	1310/15199 (8.6)	102/1111 (9.2)	1208/14088 (8.6)	.488
Ejection fraction, mean (SD), %	49.58 (10.27)	49.32 (10.34)	49.60 (10.26)	.392
Operative risk factors				
Operation type				<.001
CABG	14423/15580 (92.6)	835/1129 (74)	13588/14451 (94)	
VALVE	711/15580 (4.6)	186/1129 (16.5)	525/14451 (3.6)	
CABG + valve	446/15580 (2.9)	108/1129 (9.6)	338/14451 (2.3)	
Operative status				.085
Elective	13304/15488 (85.9)	948/1119 (84.7)	12356/14369 (86)	
Urgent	2154/15488 (13.9)	166/1119 (14.8)	1988/14369 (13.8)	
Emergent	30/15488 (0.2)	5/1119 (0.4)	25/14369 (0.2)	
CPB	15257/15574 (98)	1114/1127 (98.8)	14143/14447 (97.9)	.029
IABP	407/15554 (2.6)	76/1126 (6.7)	331/14428 (2.3)	<.001
Radial artery used as grafts	1419/15565 (9.1)	49/1125 (4.4)	1370/14440 (9.5)	<.001
Number of vein grafts, mean (SD)	2.37 (1.06)	2.15 (1.31)	2.39 (1.03)	<.001
Perfusion time, mean (SD), min	76.05 (29.29)	90.68 (45.54)	73.21 (29.13)	<.001

CVA indicates cerebrovascular accident; CCS, Canadian Cardiovascular Society Angina Score; CHF, congestive heart failure; CPB, cardiopulmonary bypass; IABP, intra aortic balloon pump insertion; MI, myocardial infarction; PVD, peripheral vascular disease.
Data are expressed as absolute frequencies (percentages) or mean (SD).

inflammatory response ranging from the presence of inflammatory infiltrates in atrial biopsies[26] to increased concentrations of C-reactive protein.[27] Our study demonstrated that the need for IABP insertion is a predictor for postoperative new-onset atrial fibrillation. The results of Kannell et al,[28] agree with our results. IABP is usually necessary because of severe myocardial dysfunction secondary to myocardial necrosis, resulting in heart failure. Severe left ventricular dysfunction and congestive heart failure are associated with a greater risk for the development of AF. The use of beta-blockers starting in the preoperative period has been shown to decrease the incidence of postoperative AF in some studies.[29,30] Because sympathetic activation might facilitate postoperation AF

TABLE 2. **Perioperative and Operative Risk Factors Associated With the Development of Atrial Fibrillation (AF) Post Cardiac Surgery**

Factors	OR 95% Confidence Interval	*P*
Age		<.001
≤50	Ref. category	
51-60	1.64 (1.343-2.004)	
≥60	2.306 (1.897-2.805)	
Renal failure	1.477 (1.004-2.173)	.047
Congestive heart failure	1.633 (1.398-1.907)	<.001
Beta-blocker consumption	0.71 (0.612-0.824)	<.001
Operation type		<.001
CABG	Ref. category	
VALVE	4.074 (3.228-5.141)	
CABG + VALVE	2.122 (1.588-2.835)	
Perfusion time	1.006 (1.004-1.008)	<.001
IABP insertion	1.675 (1.26-2.229)	.003

Hosmer-Lemeshow goodness of fit test; P-value=.37.
Area under the ROC curve (AUC); c=0.75032.

in susceptible patients, and given the increased sympathetic tone in patients undergoing cardiac surgery, beta-blocker drugs have been shown to prevent this postoperative arrhythmia. Our study shows that preoperative beta-blocker agent use had a protective effect on postoperative AF. In this study, the mean hospital and postoperative length of stay was 5.1 days and 4.1 days longer, respectively, in subjects with new-onset AF than subjects without AF (*P*<.001). Borzak et al[31] noted that subjects with AF had a longer length of stay in the ICU (2.7 days for subjects with AF vs 1.7 days for subjects without AF) and on the ward (9.4 days for subjects with AF vs 6.3 days for subjects without AF). Almassi et al[32] reported a longer stay in the hospital: 3 days more in the ICU for patients with AF versus 2 days for patients without AF. Thus, the reported LOS varies widely between centers. This variance may be due to time (more recent trend to rapid discharge), and variations in ICU admission criteria. However, all reports agree

TABLE 3. **Postoperation Atrial Fibrillation (AF) Effect on Mortality and Resource Utilization in Patients With Cardiac Operation**

Outcome	Total	AF	No-AF	*P*
Mortality	151/15580 (1)	43/1129 (3.8)	108/14451(0.7)	<.001
Readmission	133/15539 (0.9)	50/1127 (4.4)	83/14412 (0.6)	<.001
PLOS, mean (SD), d	8.03 (5.2)	11.86 (7.34)	7.73 (4.87)	<.001
HLOS, mean (SD), d	16.64 (7.53)	21.39 (9.94)	16.27 (7.18)	<.001

Data are expressed as absolute frequencies (percentages) or mean (SD).
HLOS indicates hospital length of stay; PLOS, post surgery length of stay.

TABLE 4. **Post Operative Atrial Fibrillation Effect on Mortality and Resource Utilization by Logistic Regression Analysis Adjusted for Confounders**

Outcome	OR (95% CI)	*P*
Mortality	2.997 (1.952-4.602)	<.001
Readmission	1.456 (1.168-3.552)	<.001

CI indicates confidence interval; OR, odds ratio.

TABLE 5. **Post Operative Atrial Fibrillation Effect on Mortality and Resource Utilization by Linear Logistic Regression Analysis Adjusted for Confounders**

Outcome	β	95% CI	*P*
PLOS, d	1.647	1.011-2.144	<.001
HLOS, d	1.116	1.168-3.44	<.001

HLOS indicates hospital length of stay; PLOS, post surgery length of stay.

that patients with AF stay in the ICU and on the ward longer, and our results subscribed to those of others. Determining the reason for the lengthened stay is difficult. To some degree, the difference might be explained by more hospitalization time required to execute interventions to convert to sinus rhythm, check out stabilization of the therapy (e.g., therapeutic amiodarone levels), or institute and monitor use of anticoagulants for subjects who do not convert. Our study revealed higher early readmission rate and in-hospital mortality rate in patents with postoperative AF than without AF (4.4% vs 0.6%, and 3.8 % vs 0.7%, respectively).

This may be related to higher morbidity in patients with postoperative atrial fibrillation[33] which cause higher readmission rate. Mathew et al[34] demonstrated postoperative AF adversely affects the surgical morbidity and mortality and consequently leads to a longer hospital stay and more use of resources, increasing the cost of care.

The limitations to our study include first, it was an observational design. Second, the study was

not designed specifically to look at postoperative AF. As such, we could not establish with certainty a direct causality between the predictors listed and postoperative AF. Third, we could not determine the exact timing of postoperative events such as neurologic events or MI from our data. It is therefore difficult to establish a temporal relationship between these events and AF. Thus we could not evaluate the effect of postoperative AF on morbidity. Fourth, the majority of our patients (73.4%) were male; therefore, the effect of sex on postoperative AF could not be evaluated. Fifth, we did not have exact data about drug history (ACE inhibitors) of patients and thus we could not evaluate its effect on postoperative AF.

CONCLUSIONS

Atrial fibrillation often occurs after cardiac surgery and is associated not only with increased morbidity and mortality but also with increased resource utilization. Strategies to identify the patients at risk and to modify these risk factors by aggressive prophylactic measures should lead to a lower incidence of AF and a reduced morbidity, mortality and resource utilization rate for patients undergoing cardiac surgery.

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