Does Pulmonary Artery Venting Decrease the Incidence of Postoperative Atrial Fibrillation after Conventional Aortocoronary Bypass Surgery?

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ABSTRACT

Objectives: In this study, we tested the hypothesis that pulmonary artery venting would decrease the incidence of atrial fibrillation after coronary artery bypass surgery.

Methods: This prospective study included 301 patients who underwent complete myocardial revascularization with cardiopulmonary bypass in our department during a 2-year period. The patients were randomly divided into 2 groups: group I included 151 patients who underwent aortic root venting and group II included 150 patients who underwent pulmonary arterial venting for decompression of the left heart. Pre-, peri-, and postoperative risk factors for atrial fibrillation were assessed in both groups.

Results: The mean age was similar in the 2 groups. The mean number of anastomoses was significantly higher in group I (2.8 ± 0.8) than in group II (2.4 ± 0.8) (*P* = 0.001). The mean cross-clamp time was 42.7 ± 17.4 minutes in group I and 54.1 ± 23.8 minutes in group II (*P* = 0.001). The mean cardiopulmonary bypass time was 66.4 ± 46.1 minutes in group I and 77.4 ± 28.6 minutes in group II (*P* = 0.08). The incidence of atrial fibrillation was 14.5% (n = 21) in group I and 6.5% (n = 10) in group II (*P* = 0.02). Multivariate regression analysis showed that pulmonary artery venting decreased the postoperative incidence of atrial fibrillation by 17.6%.

Conclusions: Pulmonary arterial venting may be used as an alternative to aortic root venting during on-pump coronary bypass surgery, especially in patients at high risk of postoperative atrial fibrillation.

INTRODUCTION

Postoperative atrial fibrillation (AF) remains a major complication of cardiac surgery, despite continuing advances in surgical techniques and pharmacological therapies, and its incidence is on the increase. This is in part related to the progressive aging of the patient population and the frequent presence of comorbidities [Ferguson 2002]. The incidence of AF after cardiac surgery ranges between 10% and 60%, and it has been suggested that this variability reflects differences in types of procedures, patient demographics, and methods of electrocardiographic monitoring [Mathew 2004]. Patients who develop postoperative atrial fibrillation are more likely to have other complications, such as perioperative myocardial infarction (MI) or postoperative congestive heart failure or respiratory failure [Almassi 1997]. Postoperative AF is associated with longer intensive care unit (ICU) and hospital stays; as a result, the economic cost can be considerable [Aranki 1996]. Consequently, AF has become the object of intense research activity aimed at improving our insight into its etiopathogenesis, prevention, and prognosis after cardiac surgery.

Ventricle distension in patients undergoing on-pump coronary artery bypass grafting (CABG) surgery increases oxygen demand in the myocardium by increasing ventricle wall tension, impairs the subendocardial coronary arterial blood flow and contractility, and causes pulmonary edema by increasing pulmonary venous pressure. Therefore, cardiac venting is necessary during the operation [Roberts 1983; Mills 1985]. Decompression of the left chambers of the heart can be accomplished by various methods, such as the placement of a root cannula through the ascending aorta. The same cannula may be used as an antegrade route for cardioplegia, and the entry site of the cannula may be used for proximal anastomosis. Alternative routes for cardiac venting include the right superior pulmonary vein, left atrial appendix, superior wall of the left atrium, and, directly, the left atrium and left ventricular apex in patients undergoing left atriotomy. Pulmonary artery venting is another option during cardiopulmonary bypass (CPB) [Baile 1985]. Our previous experience with pulmonary artery venting and aortic venting for decompression of the left ventricle suggested that the former approach was associated with a significantly lower incidence of AF. Therefore, we decided to test the hypothesis that pulmonary artery venting would decrease the incidence of postoperative AF. Accordingly, the aim of the present study was to compare the effect of pulmonary artery versus aortic root venting on the incidence of postoperative AF in patients undergoing on-pump CABG surgery.

MATERIALS AND METHODS

This prospective study included 301 patients who underwent complete myocardial revascularization with CPB in our department during a 2-year period. All patients were operated on by the same team of 3 surgeons in a randomized manner. We included consecutive patients who met our criteria, and they were allocated, at random, into 1 of 2 operative groups by the anesthesiologist: group I (n = 151), the aortic root venting group, and group II (n = 150), the pulmonary artery venting group. The exclusion criteria included repeated revascularizations, combined carotid artery surgery and/or valve surgery, presence of preoperative AF, cerebrovascular accident, and incomplete myocardial revascularization. This study was performed in accordance with the principles of the latest version of the Helsinki Declaration. Approval of this study was obtained from the research ethics board. The 2 groups were compared with respect to the following independent variables that have been previously linked with postoperative AF: age, sex, hypertension (HT), diabetes mellitus (DM), chronic obstructive pulmonary disease (COPD), previous MI, beta-blocker use, ejection fraction (EF), the number of target coronary arteries, and functional capacity. The demographic characteristics of the patients are summarized in Table 1.

The mean age in group I was 61.4 ± 8.8 years (range, 38–69 years; 72% male) and the mean age in group II was 61.4 ± 9.5 years (range, 31–79 years; 52.7%, male) with no significant age difference between the 2 groups. The incidences of DM and MI were significantly higher in group II than in group I (P = 0.001 and P = 0.01, respectively), whereas the incidence of HT was significantly higher in group I than in group II (P = 0.001). EF was similar in the 2 groups.

Operative Technique

The standard 2-stage venous and ascending aortic cannulation was performed in both groups. Antegrade cold potassium blood cardioplegia was given with a dose of 10 mL/kg and systemic hypothermia (28°C) was used for myocardial protection. In group I, antegrade cardioplegia was administered via aortic root cannula, whereas in group II it was given via a 16-gauge needle from the ascending aorta. Proximal anastomoses were performed under cross-clamp (CC) in both groups. Pulmonary venting was performed as follows: a small incision was made in the main pulmonary artery and the venting catheter was inserted. After the CC was removed and cardiac beating started, 4-0 prolene purse-string sutures were placed around the pulmonary venting catheter and the incision was closed. No surgical complications occurred related to the pulmonary artery procedure. The number of anastomoses and the CC and CPB times were recorded. Postoperative total drainage volume; number of blood transfusions required; duration of intubation; need for medical (bronchodilator), mechanical, and manual respiratory therapy after extubation (nasotracheal aspiration, continuous positive airway pressure); and need for reintubation were evaluated to determine the effect of each predictive factor on the occurrence of postoperative Afzal patients were continuously monitored during the ICU stay. In the ward, routine clinical assessments were performed every hour and a 12-lead electrocardiogram (ECG) was obtained once a day. Continuous monitoring was reinitiated in the case of any arrhythmia. When needed during the postoperative period, magnesium and potassium replacements were done to keep plasma levels within the normal range. In patients using beta-blockers during the preoperative period, the regimen was restarted immediately after extubation. AF was routinely

Table 1. Demographic Characteristics of the Patients

Variables	Group I (n = 151)	Group II (n = 150)	P
Age, mean ± SD, years	61.4 ± 8.8	61.4 ± 9.5	NS
Male sex, n (%)	108 (72%)	79(52.7%)	0.01
Hypertension, n (%)	112 (74%)	32 (21%)	0.0001
Diabetes mellitus, n (%)	52 (34%)	107 (71%)	0.0001
Previous MI, n (%)	23 (15%)	40 (27%)	0.02
COPD, n (%)	35 (23%)	45 (30%)	NS
EF, mean ± SD, %	51 ± 8.8	50 ± 7.2	NS
Beta-blocker use	62 (41%)	55 (37%)	NS

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Table 2. Perioperative Variables of the Patients

Variables	Group I (n = 151)	Group II (n = 150)	*P*
AF, n (%)	21 (14.5%)	10 (6.5%)	0.02
CC time, mean ± SD, minutes	42.7 ± 17.4	54.1 ± 23.8	0.001
CPB time, mean ± SD, minutes	66.4 ± 46.1	77 ± 28	NS
Number of anastomoses, mean ± SD, n	2.8 ± 0.8	2.4 ± 0.8	0.001
Inotropic agent use, n (%)	18 (12%)	12 (8%)	NS
Total drainage, mean ± SD, mL	531 ± 324	514 ± 346	NS
Blood transfusion, mean ± SD, units	1.2 ± 0.9	1.2 ± 1.0	NS
Duration of intubation, mean ± SD, hours	8.5 ± 4.6	8 ± 3.2	NS
Bronchodilator use, n (%)	36 (24%)	15 (10%)	0.001
Need for nasotracheal intubation, n (%)	20 (%)	5 (%)	0.002
Reintubation, n (%)	7 (4.6%)	0 (-)	0.001
Duration of ICU stay, mean ± SD, days	1 ± 0.2	1 ± 0.1	NS
Duration of hospitalization, mean ± SD, days	6.6 ± 4.4	6.8 ± 1.6	NS

treated with amiodarone. For the purposes of this study, AF was defined as sustained AF lasting for more than 5 minutes, requiring pharmacological intervention or electrical cardioversion, or both. The length of stay in the ICU and the ward were also recorded in each group for comparison.

The effect of all risk factors on the occurrence of postoperative AF as assessed by multivariate regression analysis is shown in Tables 1 and 2.

Statistical Analysis

Statistical analyses were performed using the Statistical Package for the Social Sciences statistical program (SPSS 10.0; SPSS, Inc, Chicago, IL, USA). Data are expressed as mean ± standard deviation (SD). Pearson's chi-square test was used to compare categorical variables, and the Mann-Whitney U test was used for the comparison of continuous variables. Multivariate linear regression analysis was used to determine the level of relationship between the independent variables (predictive factors shown in Table 1 and 2) and the

dependent variable (postoperative AF). A *P* value less than 0.05 was considered significant.

RESULTS

The mean CC time in group I was 42.7 ± 17.4 minutes, compared to 54.1 ± 23.8 minutes in group II (*P* = 0.001) (Table 2). The mean CPB time was 66.4 ± 46.1 minutes in group I and 77.4 ± 28.6 minutes in group II (not significant [NS]; *P* = 0.08). The mean number of anastomoses in group I was higher than in group II, and this difference was statistically significant (2.8 ± 0.8 versus 2.4 ± 0.8, respectively; *P* = 0.001). There were no significant differences between the groups with regard to the mean duration of intubation (8.5 ± 4.6 in group I and 8.0 ± 3.2 hours in group II). However, significantly more patients required nasotracheal aspiration (*P* = 0.002), bronchodilator treatment (*P* = 0.001), and reintubation (*P* = 0.001) in group I than in group II (Table 2). No significant differences were found with regard to the mean

duration of stay in the ICU (1 ± 0.2 days in group I and 1 ± 0.1 days in group II) or in the hospital (6.6 ± 4.4 days in group I and 6.8 ± 1.6 days in group II).

The incidence of AF was 14.5% (n = 21) in group I and 6.5% (n = 10) in group II and the difference was statistically significant (P = 0.02). Multivariate regression analysis showed that among the risk factors shown in Tables 1 and 2, only the type of venting (P = 0.042), history of HT (P = 0.007), and inotropic agent use (P = 0.039) had a statistically significant effect on the occurrence of AF. Therefore, in this analysis, the type of venting for decompression of the left heart during CPB emerged as an independent factor for the occurrence of postoperative AF, with a 17.6% lower incidence of AF in the pulmonary artery venting group (P = 0.042).

DISCUSSION

Postoperative AF is a common complication following cardiac surgery and has adverse effects on patient recovery, morbidity, and costs as well as on early and late mortality [Maisel 2001; Mathew 2004; Villareal 2004]. As a consequence, considerable effort has been made to identify pharmacologic agents or other strategies that can reduce the incidence of this arrhythmia [Maisel 2001; Mathew 2004]. Management of AF in this setting is often frustrating. Therefore, we tested whether the type of venting, which enables distension of the myocardium, affected the incidence of postoperative AF. We found a significantly lower incidence of postoperative AF after CABG in the pulmonary artery venting group compared to the aortic venting group.

The pathophysiology of AF after cardiac surgery is not precisely known, but the mechanisms are thought to be multifactorial. A reentry mechanism is regarded as the main contributor. The phenomenon of altered automaticity requires an atrial structural substrate, which may reflect an association with multiple preoperative predisposing factors. Operative and postoperative factors may also contribute to the development of this structural substrate. Among the preoperative risk factors, advanced age and HT have been implicated as the main causes of AF. In particular, aging is the variable that exhibits the most significant association with the development of AF, not only after cardiac surgery but also in the general population [Mathew 2004]. Atrial fibrosis and dilation, both more common in the elderly, may explain alterations and loss of electrical coupling among atrial myocardial fibers. In our patient population, the 2 groups were similar with respect to mean age. Therefore, we did not evaluate the effect of age on the occurrence of AF after CABG. The role of HT as risk factor for AF is established but still incompletely known. The risk of AF in hypertensive compared with normotensive subjects was increased by 1.9 times in the Framingham Heart Study [Kannel 1982] and 1.4 times in the Manitoba Follow-up Study [Krahn 1995]. Although history of HT had a statistically significant effect on the occurrence of AF in our patient population, multivariate regression analysis showed that it is not an independent factor for the postoperative AF.

On the other hand, some other triggering events have also been documented in association with autonomic nervous system imbalance [Hill 2002]. The activation of the sympathetic nervous system probably contributes to the onset and maintenance of AF after cardiac surgery. Preoperative alterations of the autonomic nervous system have been observed independently from the type of the procedure. In the general population an increased sympathetic tone, as assessed by heart rate variability, has been documented immediately prior to the onset of AF [Herweg 1998]. A reduction in heart rate variability has been demonstrated in patients undergoing CPB, suggesting the existence of postoperative fluctuations in the cardiac autonomic tone. A hyperresponsiveness of the autonomic nervous system would reduce the atrial refractory period, thus promoting the onset of the arrhythmia [Hill 2002]. When an aortic venting catheter is preferred for decompression of the left heart, a much greater tendency for hematoma formation in the adventitia of the aorta is observed, since the aortic vent catheter is inserted into the beating heart while there is still considerable pressure in the aorta. In contrast, in pulmonary artery venting, antegrade cardioplegia is applied via a 16-gauge needle from the ascending aorta following CC, while pulmonary artery venting decompresses the left heart. Therefore, less extensive adventitial hematoma is expected when pulmonary artery venting is preferred. When aortic venting is preferred, much more resection of adventitia is inevitably needed to achieve proximal anastomosis, which increases the likelihood of an autonomic nervous system imbalance due to the much more extensive injury to sympathetic chains around the aorta.

In current clinical practice, cardioplegia is applied via a double-lumen aortic root cannula placed into the ascending aorta, after CC during on-pump coronary bypass surgery, and then left ventricle decompression is effectively performed. Although a proximal anastomosis can be constructed without removal of the aortic cannula, the cannula is generally removed during proximal anastomosis. This is one of the major disadvantages of this method, since left ventricular decompression cannot be continued until the proximal anastomoses are completed. Venting during reperfusion, after the removal of the CC, decreases the pressure in the left ventricle and therefore decreases the intramyocardial-epicardial/endocardial pressure gradient and left ventricle wall tension. As a result, myocardial oxygen demand is decreased [Macnaughton 1992]. This is especially important in the case of left ventricular hypertrophy and ventricular fibrillation. The second disadvantage is that diastolic arrest is present during CC and the aortic valve is closed. To obtain effective left ventricular decompression, manual compression over the left ventricle may be necessary to maintain the passage of the blood to the aorta. Presence of an extra double-lumen cannula and the presence of a complex surgical field are other disadvantages of the aortic root venting method.

Macnaughton et al., in their Technetium 99m study, observed that pulmonary arterial venting maintains effective left ventricle decompression [Macnaughton 1992]. Pulmonary arterial venting enables the aspiration of the blood coming from the right heart through the coronary sinuses, part of the systemic venous blood, as well as blood from the thebesian veins draining to the left atrium and blood from the

bronchial arteries draining to the pulmonary veins. Manual compression of the left ventricle may also sometimes be necessary in this method. Furthermore, the mitral valve is incompetent during cardiac arrest or fibrillation. In this case, the left atrium and left ventricle acted as a single chamber. As a result, a pulmonary arterial vent can aspirate the blood from both chambers. This is not surprising, because there are no valves in the pulmonary circulation [Murray 1988]. The advantages of pulmonary arterial venting are the continuation of the decompression of the left ventricle in the early reperfusion period, thereby decreasing the myocardial oxygen demand, enabling a simple visual field in the surgical area and prevention of pulmonary stasis and edema.

The systemic inflammatory response against CPB also causes an increase in microvascular permeability and pulmonary dysfunction [Tennenberg 1990]. As clinicians, we encounter different forms of this phenomenon in daily practice quite frequently. Lung injury after CPB is characterized by increased extravascular pulmonary fluid due to endothelial injury and atelectasis [Macnaughton 1992]. In our study, the use of pulmonary artery venting also reduced the risk of lung injury during CPB, which is also a risk factor for AF. Although there were no significant differences between group I and group II in terms of the mean duration of postoperative intubation ($P = 0.3$), significantly lower rates for nasotracheal aspiration, bronchodilator need, and reintubation were observed in group II ($P = 0.001$). Improved postoperative pulmonary function is associated with improved physiological status and may speed up the recovery of myocardial functions, all of which are probably associated with a decreased incidence of AF during the postoperative period. On the other hand, serious left ventricular distension has also been reported to occur with pulmonary arterial venting [Roach 1992], and insufficient pulmonary blood flow may result in a failure of pulmonary circulation and lung injury [Ege 2004]. However, insufficient pulmonary circulation may be corrected by increasing the aortic perfusion pressure [Dodd-o 2004]. Furthermore, pulmonary arterial venting did not result in any postoperative respiratory problems in our study.

There are some reports that beta-blockers are effective in preventing postoperative AF [White 2002], and most identified metaanalyses have demonstrated that beta-blockers significantly reduced the incidence of postoperative AF [Koniari 2010]. Some studies have shown that the use of preoperative beta-blockers and early postoperative withdrawal have been implicated in the etiology of postoperative AF [Andrews 1991; Kowey 1992]. Therefore, reinstitution of a beta-blocking agent immediately after operation can decrease the incidence of postoperative AF. However, there are also some reports that reliance on recommending beta-blockers alone after surgery leaves a significant number of patients at risk of postoperative AF [Burgess 2006], and the preoperative use of beta-blockers had no relation to the development of AF [Hashemzadeh 2013]. In summary, the use of beta-blockers for prophylaxis of atrial fibrillation remains less than expected, and more clinical trials with robust and clinically relevant outcomes are needed. Amiodarone has come to the fore as the most effective treatment protocol in the treatment of AF. In our clinic amiodarone is used routinely in the treatment of postoperative AF.

Our prospective study had some limitations, the most important of which was that all of the patients were operated on by the same surgical team, which included 3 different surgeons. Therefore, the CC time and CPB times were different in the 2 groups. However, AF rates were significantly lower in group II than in group I, despite the longer CC and CPB times in group II. Moreover, the multivariate regression analysis showed no effect of CC and CPB times on the incidence of postoperative AF. Another limitation was that the monitoring was intermittent in the ward, so many episodes of short-term or asymptomatic AF may have been missed.

In conclusion, pulmonary arterial venting may be used as a safe alternative to aortic root venting during on-pump coronary bypass surgery, particularly in patients at a high risk of postoperative AF.

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