Background. Postoperative atrial fibrillation (POAF) is the most common complication among patients undergoing cardiac surgery. However, data on the economic burden and resource utilization associated with POAF in Asian population are limited. The present study aimed at estimating medical costs attributable to POAF after cardiac surgery in Thai population. Methods. We analysed data from claims database of patients who underwent valve replacement, coronary artery bypass grafting (CABG), or a combination of both procedures at a tertiary-care, academic hospital in Thailand. Multiple linear regressions of log-transformed costs were developed with the occurrence of POAF and preoperative patient characteristics as covariates. After back-transformation to the original scale, costs attributable to POAF were estimated from the mean difference between patients with and without POAF. Results. Of 711 patients undergoing cardiac surgery, 241 (30.94%) developed POAF over a median hospitalization of 10 days. Patients with POAF utilized more resources than those without POAF. POAF was an independent predictor and increased cost by 23% in linear regression model. On average, patients with POAF had higher medical costs than those without POAF (269,000 versus 218,999 Thai Baht (THB)) with a mean difference of 50,000 THB (1,667 USD). The difference was observed in patients undergoing isolated valve surgery (47,761 THB (1,592 USD), 95% CI: 39,809–55,712), CABG (50,865 THB (1,696 USD), 95% CI: 37,233–64,496), and a combination of both procedures (72,287 THB (2,410 USD), 95% CI: 49,910–94,405). Conclusions. In a single-institution study in Thailand, POAF is associated with increased resource use and medical costs among patients undergoing cardiac surgery. Effective strategies to prevent POAF should be implemented to reduce its economic burden.
features as independent variables to identify potential confounders. Potential confounders were defined as those variables associated with the log-transformed cost with a \( p \) value less than 0.2 on univariable analysis. The occurrence of POAF together with all potential confounders was forced to enter the multiple linear regression model, regardless of their statistically significant contribution to the final model. The heteroscedasticity of the regression residuals on the log scale was examined with White’s test [12], and no significant heteroscedasticity was observed. Thus, the adjusted costs were retransformed back to their original scales with correction of retransformation bias using Duan’s smearing estimator [13]. The attributable cost of POAF was determined by the mean difference of adjusted costs between patients with and without POAF.

Statistical analyses were performed using the Stata software. Unless otherwise indicated, the tested results were considered statistically significant with a \( p \) value < 0.05.

2.3. Ethical Issues. The study protocol was approved by the Institutional Review Board on Human Research at Naresuan University and the Human Research Committee at the study hospital prior to data collection.

3. Results

3.1. Patient Characteristics. The cohort consisted of 711 patients undergoing cardiac surgery during the study period. As shown in Table 1, the mean age was 56.07 ± 12.58 years and more than half of the cohort were male. Hypertension was the most prevalent (32.63%) comorbid condition. The majority (68.50%) underwent isolated valve surgery, while 24.61% and 6.89% underwent isolated CABG and concomitant CABG with valve surgery, respectively.

Overall, POAF developed in 220 patients (30.94%) during a median length of stay (LOS) of 10 days (interquartile range 3–17 days). Compared to those without POAF, patients with POAF were older (57.93 ± 12.00 versus 55.24 ± 12.58; \( p = 0.008 \)) and had fewer diagnoses of atrial fibrillation prior to operation (9.09% versus 15.07%; \( p = 0.03 \)), but more histories of chronic obstructive pulmonary disease, diabetes mellitus, dyslipidemia, hypertension, and ischemic heart diseases.

3.2. Resource Utilization. Patients with POAF spent 1 more day in hospital compared to those without POAF (median LOS, 11 days versus 10 days; \( p < 0.01 \)). The resource utilization among patients with and without POAF was compared, as shown in Table 2. On average, patients with POAF incurred higher unadjusted costs during hospitalization in every cost component \( (p < 0.001) \). The greatest difference was observed in costs associated with utilization of pharmacy products (19,210 THB (640 USD)) accounting for 35% of the total mean difference.

3.3. The Attributable Cost of POAF. We adjusted the effects of potential confounders on the association between medical costs and the occurrence of POAF by developing a multivariable linear regression model. Because costs were heavily
right skewed, we log-transformed the total costs prior to regression modelling. Table 3 shows that, after adjusting for other variables, POAF still contributed significantly to the total cost ($\beta = 0.21; 95\% \text{ CI} 0.15–0.27; p < 0.001$). In other words, a patient undergoing cardiac surgery who developed POAF had 23% higher medical cost during hospitalization than a patient who did not develop POAF.

Table 4 shows that an occurrence of POAF incurred higher costs to patients undergoing either isolated valve replacement, CABG, or a combined procedure. The highest attributable cost was observed in patients undergoing a combined procedure (72,287 THB (2,410 USD) per patient).

4. Discussion

The results of the present study demonstrate that POAF is associated with higher medical cost independently of preoperative characteristics among patients undergoing cardiac surgery. The findings underscore a significant contribution of POAF to economic burden among patients who undergo cardiac surgery. To illustrate, about 10,000 patients undergo cardiac surgery in Thailand each year, and one-third of these patients will develop POAF. Given that POAF increases medical cost by 50,000 THB (1,667 USD) per patient according to our study, this will incur an additional cost of 170 million THB (5.7 million USD) annually. Thus, an effective intervention to prevent POAF or mitigate its severity if implemented would result in a significant reduction of health-care expenditure for the country.

The evidence that POAF prevention may save the cost of care in cardiac surgery can also be inferred from the cost-effectiveness study of an intervention to prevent POAF. For example, Gillespie et al. [5] reported that use of beta-blockers for prophylaxis of POAF in cardiac surgery was associated with a significant reduction in the incidence of...
POAF, hospital LOS, and total hospital cost. The results of our study agree with this finding and further emphasize beneficial effects of POAF prevention in cardiac surgery to Asian population.

Our data indicate that POAF was associated with more resource use from all service departments. In support of this observation, our results concurred with those reported by Hravnak et al., who found that POAF in patients undergoing isolated CABG resulted in more resource utilization, including laboratory test and pharmacy products [4]. The incremental cost was greatest in room services accounting for 26% of the total difference [4]. In our study, the major resource utilization driving the incremental cost of POAF was the pharmacy product utilization accounting for 35% of the total difference. This disparity is possibly explained by a variation in how service costs are established between hospitals, further emphasizing the confined application of economic data among various institutions and geographic locations. More importantly, both studies provided consistent evidence that the POAF incurs higher resource utilization in cardiac surgery patients.

We observed that patients with POAF stayed in hospital about 1 day longer than those without POAF. The difference in LOS would not totally explain the higher costs associated with POAF in this study. Consistent with our findings, previous studies reported that the LOS differed by approximately 1 day despite much higher costs observed among patients with POAF [4, 6]. Other studies reported a longer incremental LOS, although the results varied widely from 3 to 8 days [5, 7–10]. In a more recent study, the occurrence of POAF after a combined CABG and aortic valve replacement increased hospital LOS by 3 days with an incremental cost of 9,000 USD [14]. This discrepancy in LOS possibly reflects the difference in study population, practice pattern among institutions, and study designs. Despite the difference in LOS, all studies consistently observed an increase in medical costs associated with POAF [4–10].

Although the cost attributable to POAF was observed in all types of cardiac surgery, the highest incremental cost was associated with the combined procedure. Our results agree with those reported by Mahoney et al. [14], who found that the incremental cost associated with POAF was highest among patients undergoing a combined procedure. Additionally, LaPar et al. [15] reported that patients who underwent combined CABG and valve replacement accrued higher costs and longer LOS than did those who had an isolated procedure. Patients with combined cardiac surgery had higher rates of overall complication, and this may drive incremental cost of combined cardiac surgery [15]. We postulated that a greater incremental cost of POAF in patients undergoing a combined procedure was possibly due to more frequent complication related to POAF. From our data, medical costs were not much different among patients who underwent an isolated or a combined procedure and did not develop POAF (Table 4), suggesting that POAF itself likely incurred higher costs after a combined procedure. However, we cannot exclude the possibility of data imprecision due to a smaller number of patients undergoing a combined procedure. This finding should be further explored to gain additional insights on the economic burden of POAF in relation to distinct types of cardiac surgery and the impact of its prevention.

Some limitations of the present study merit discussion. First, this study utilized a cohort of patients to determine the attributable cost of POAF. Due to its retrospective and observational nature, the present study was subject to several factors confounding the association between cost and POAF. We tried to alleviate this problem by developing a regression model to adjust for preoperative characteristics; however, we acknowledge the presence of other unmeasured confounders. Previous studies revealed that preoperative together with intraoperative and postoperative characteristics explained variation in total costs of cardiac surgery better than preoperative factors alone [16–18]. Thus, the estimated cost in this study may not be totally adjusted for. Of note, most of the previous studies estimated the attributable cost of POAF by determining the difference in unadjusted costs between patients with and without POAF [4–8]. Such method would also subject to several potential confounders due to difference in baseline characteristics and disease severity of the participants. Second, the present study utilized secondary database as a data source, this may raise the question of result validity. Miscategorization of POAF could have occurred if the POAF was perceived as insignificant and was not recorded into patient charts by care providers. The lack of ECG records from claims database prevented us from verifying the occurrence of POAF. This could lead to an underestimation of POAF incidence and false estimation of the POAF cost. Last, this study was conducted with data from a single institution, and this may limit generalizability of the result to other settings. However, the incidence of POAF and its effect on resource utilization observed in our study were well consistent with other studies [4–9]. We therefore believe that the results likely provide a valid and generalizable estimate of the attributable cost of POAF and could be used in assessing the

| Types of surgery             | With POAF (THB) | Without POAF (THB) | Mean difference (THB) | 95% CI          | p value* |
|-----------------------------|-----------------|-------------------|----------------------|----------------|----------|
| Isolated valve replacement  | 268,740         | 220,979           | 47,761               | 39,809–55,712  | <0.001   |
| Isolated CABG              | 266,500         | 215,635           | 50,865               | 37,233–64,496  | <0.001   |
| Combined valve replacement and CABG | 282,747       | 210,460           | 72,287               | 49,911–94,406  | <0.001   |
| All patients               | 269,000         | 218,999           | 50,001               | 43,440–56,561  | <0.001   |

*Independent t-test. CABG, coronary artery bypass graft; POAF, postoperative atrial fibrillation; THB, Thai Baht.
cost-effectiveness of interventions to prevent an occurrence of POAF among patients undergoing cardiac surgery.

5. Conclusions

In a single-centre study in Thai population, POAF is consistently associated with an increase in medical costs among patients undergoing valve surgery, CABG, or the combination. Effective strategies to prevent POAF should be implemented to reduce its economic burden.

Conflicts of Interest

The authors declare no conflicts of interest in the present study.

Authors’ Contributions

Pattamawan Kosuma carried out the study design, analysed data, and drafted the manuscript. Sitichok Wachirasrisirikul participated in the study design and drafted the manuscript. Arom Jedsadayanmata conceived the study, participated in the study design, and drafted the manuscript. All authors read and approved the final manuscript.

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