The effect of posterior pericardiotomy after thoracic aortic surgery

Yasumi Maze (ymze.19651229@gmail.com)
Ise Red Cross Hospital
Toshiya Tokui
Ise Red Cross Hospital
Masahiko Murakami
Ise Red Cross Hospital
Daisuke Yamaguchi
Ise Red Cross Hospital
Ryosai Inoue
Ise Red Cross Hospital
Koji Hirano
Ise Red Cross Hospital
Bun Nakamura
Mie University Hospital
Hisato Itou
Mie University Hospital

Research Article

Keywords: Postoperative atrial fibrillation, posterior pericardiotomy, thoracic aortic surgery

Posted Date: March 22nd, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1464311/v1

Abstract

Background

Postoperative atrial fibrillation is a common complication of cardiovascular surgery. We aimed to examine the effectiveness of posterior pericardiotomy in reducing the incidence of postoperative atrial fibrillation after thoracic aortic surgery.

Methods

The study included 201 patients who underwent thoracic aortic open surgery between January 2014 and November 2021. We compared surgical outcomes between patients who underwent posterior pericardiotomy and those who did not. We also compared the preoperative characteristics and surgical outcomes between patients who showed postoperative atrial fibrillation and those who did not. Multivariate analysis was performed to determine the risk factors for postoperative atrial fibrillation.

Results

The group that did not undergo posterior pericardiotomy had significantly longer mechanical ventilation duration than the group who did in the overall ($p=0.005$) and propensity-matched cohorts ($p=0.001$). The lengths of intensive care unit and hospital stays were significantly longer in the group that did not undergo posterior pericardiotomy than in the group that did in the overall and propensity-matched cohorts. Postoperative atrial fibrillation occurrence did not differ significantly between the two groups. Late pericardial tamponade occurred significantly more frequently in the group that did not undergo posterior pericardiotomy than in the group that did in the overall ($p=0.03$) and propensity-matched cohorts ($p=0.03$). Advanced age was independent predictors of postoperative atrial fibrillation.

Conclusions

Posterior pericardiotomy has no effect on reducing postoperative atrial fibrillation after thoracic aortic surgery. Posterior pericardiotomy reduced the occurrence of late pericardial tamponade, length of ICU stay, length of hospital stay, and mechanical ventilation duration after surgery.

Background

Although the incidence of postoperative atrial fibrillation (POAF) after cardiovascular surgery has been reported to be 20–40% [1–4], most of these studies were conducted after coronary artery bypass grafting (CABG) or aortic valve replacement (AVR), and few were reported after thoracic aortic surgery [5, 6]. The onset of POAF increases the risk of postoperative stroke and death, and also leads to an increase in the duration and cost of hospitalization [2–4, 7]. Therefore, prevention of POAF is important. Previous studies have reported that posterior pericardiotomy (PP) reduces POAF [8, 9], and more recent reports have reviewed the POAF-reducing effect of posterior pericardial drainage or PP [10–13]. However, although there have been cohort studies examining the POAF-reducing effects of pericardial drainage or PP after

CABG or AVR or after CABG, AVR, and thoracic aortic surgery, these effects have not been evaluated after thoracic aortic surgery alone. We have been performing PP in thoracic aortic surgery to reduce POAF since 2018. The purpose of this study was to examine the POAF-reducing effect of PP in thoracic aortic surgery.

Subjects

From January 2014 to November 2021, 332 patients underwent open thoracic aortic surgery at our institution. The following patients were excluded from the study population:

- Patients who did not undergo selective cerebral perfusion
- Patients with previous atrial fibrillation (AF) or paroxysmal atrial fibrillation and a history of ablation treatment
- Patients receiving anti-arrhythmic drugs preoperatively
- Patients with hyperthyroidism or chronic obstructive pulmonary disease
- Patients undergoing combined cardiac procedures with valves and/or CABG
- Patients undergoing redo procedures
- Patients receiving intra-aortic balloon pumping and/or extracorporeal membrane oxygenation support
- Patients requiring resuscitation with preoperative cardiopulmonary arrest
- Cases of hospital death and, re-exploration for bleeding
- Patients receiving mechanical ventilation management for 72 h or more after surgery
- Patients with postoperative reintubation
- Patients with postoperative Modified Rankin Scale [14] grade 5

After excluding the 131 patients who met these exclusion criteria, a total of 201 patients were included.

Methods

Ethical statement

All surgical and clinical data collection were performed at Ise Red Cross Hospital, Ise, Japan. Clinical outcome data were obtained from the hospital's patient records.

This study was approved by the Institutional Review Board of Ise Red Cross Hospital (11/2/2021, approval number ER2021-52), and the need for informed consent was waived due to the retrospective nature of the study. All methods were performed in accordance with the relevant guidelines and regulations.

Study design

The patients were divided into two groups: those in the PP group underwent posterior pericardiotomy while those in the non-PP group did not. We compared the preoperative characteristics, operative data, and postoperative outcomes between the two groups. In addition, the 201 patients were grouped on the basis of the presence of POAF, and the preoperative characteristics, intraoperative data, and postoperative outcomes in the POAF and non-POAF groups were compared to determine the risk factors for POAF.

Operative techniques

Anesthetic medication and surgical techniques were similar in both groups. The operation was performed using median sternotomy in all the patients. A regular open distal anastomosis was performed under moderate hypothermic circulatory arrest (25°C) and antegrade selective cerebral perfusion. Before cardiopulmonary bypass (CPB) withdrawal, a longitudinal 5cm incision was made parallel and posterior to the left phrenic nerve [11] in order to ensure better drainage of the pericardium into the left pleural cavity. However, patients who could not tolerate cardiac abduction or had dense adhesion of the left lung did not undergo posterior pericardiotomy (non-PP group). We have been performing PP since 2018, and patients who underwent surgery before 2018 were included in the non-PP group. Spiral drains were inserted into the pericardium (retrocardiac) and anterior mediastinum in all patients. If the mediastinal pleura was opened by an intraoperative procedure and the pleural cavity was opened, a chest tube was inserted into the pleural cavity regardless of the presence of PP. The pericardium was closed anteriorly as much as possible, and routine chest closure was performed.

A single-branch prosthesis (J Shield Neo; Japan Life Line, Tokyo) was used in ascending aortic or hemiarch replacement, a 4-branch prosthesis (J Shield Neo; Japan Life Line, Tokyo) was used in total arch replacement, and frozen elephant trunk (FET) prosthesis (J graft Frozenix®, Japan Life Line, Tokyo) was used in FET technique.

Postoperative management

Continuous suction (20 cmH_2O) was applied to the drains in the intensive care unit (ICU). The drains were milked and stripped at 30min intervals to ensure tube patency. The pericardial and mediastinal drains were removed when the drainage volume was 100 mL or less in 12 h. Chest tubes were removed when the drainage volume was 150 mL or less in 24 h.

Continuous electrocardiograms (ECGs) of patients were monitored during the first seven postoperative days. If any arrhythmia was suspected or the patient complained of palpitations, ECG monitoring was continued.

AF is defined by the following findings: (1) “absolutely” irregular R-R intervals (in the absence of complete atrioventricular block); (2) no distinct P waves on the surface ECG; and (3) an atrial cycle length (when visible) that is usually less than 200 ms [15]. Patients were considered to have POAF when an episode of AF persisted for longer than 30 s [15].

No prophylactic antiarrhythmic drugs were administered to any of the patients postoperatively. After the diagnosis of AF, if medical treatment was required, administration of agents such as beta-blockers, calcium-channel blockers, procainamide hydrochloride, and amiodarone was considered. If AF caused hemodynamic instability, cardioversion is considered. Anticoagulation with direct oral anticoagulant or warfarin potassium was considered if AF lasted for more than 48 h.

Two-dimensional echocardiography was performed between 5th and 14th postoperative days to assess the presence of pericardial effusion. In addition, computed tomography was performed between 7th and 10th postoperative days to assess the condition of the aorta. On the basis of the image data obtained in these examinations, patients who required pericardial drainage were diagnosed as showing cardiac tamponade. Most patients with cardiac tamponade demonstrated pericardial effusion of 2 cm or more on echocardiography. Additionally, cardiac tamponade presenting after more than seven postoperative days was diagnosed as ‘late pericardial tamponade.’ We defined drainage of pleural effusion or chest tube insertion after removal of the intraoperatively inserted chest tube as ‘late pleural drainage.’ The white blood cell (WBC) count and C-reactive protein (CRP) level were calculated from blood samples collected 5 to 7 days after surgery.

Postoperative management was performed by cardiovascular surgeons, and nine cardiovascular surgeons were involved in this study.

Statistical analysis

All statistical analyses were performed using the statistical software EZR (Easy R) on R commander [16]. Continuous variables are expressed as mean ± standard deviation and compared using Student’s *t*-test, whereas categorical variables are expressed as counts and percentages and compared using the χ^2 test. A 1:1 propensity score matching was performed to adjust for baseline differences and reduce confounding variables. Propensity scores were calculated using the following preoperative and operative variables: age, sex, hypertension, creatinine (Cr) level, estimated glomerular rate (eGFR), angiotensin-converting enzyme inhibitor/angiotensin receptor blocker (ACEI/ARB), beta-blocker, Ca-blocker, Japan score, Euro score, operation duration, CPB time, selective cerebral perfusion time, circulatory arrest time, cardiac arrest time, blood loss, and transfusion. After propensity score matching, a matched cohort of 79 patients per group was created. POAF was evaluated using multivariate Cox proportional hazards regression analysis. For all analyses, the statistical significance was set at $p < 0.05$.

Results

Preoperative characteristics and operative data

Baseline characteristics before matching are summarized in Table 1. The incidence of preoperative beta-blocker oral administration was significantly greater in the non-PP group (33.6% vs. 15.9%, p = 0.007). The non-PP group included significantly more cases of dissection type B (12.3% vs 3.4%, p=0.04). Also, the non-PP group included significantly more cases of elective surgery (52.2% vs. 31.8%, p = 0.005), the PP-group included significantly more cases of urgent surgery (7.9% vs 18.1%, p=0.04). All preoperative characteristics and operative data with significant intergroup differences were homogenised after propensity score matching (Table 2).

Postoperative outcomes

The postoperative outcomes are summarized in Table 3. The non-PP group showed a significantly longer mechanical ventilation duration in the overall (p = 0.005) and propensity-matched cohorts (p = 0.001). Both the length of ICU stay and the length of hospitalisation were significantly longer in the non-PP group in the overall and propensity-matched cohorts. POAF occurrence did not differ significantly between the PP and non-PP groups (before matching, p = 0.38; after matching, p = 0.26). There was no significant difference in stroke between the PP and non-PP groups (before matching, p = 0.54; after matching, p = 0.6). The amount of pericardial drainage was not significantly lower in the PP group in the overall cohorts (p = 0.09), but the difference was significant in the propensity-matched cohorts (p = 0.04). The amount of mediastinal drainage was significantly lower in the PP group in the overall cohorts and propensity-matched cohort. The duration of indwelling of the pericardial drain and mediastinal drain was significantly shorter in the PP group in the overall and propensity-matched cohorts. Late left pleural drainage occurred significantly more frequently in the non-PP group in the overall (p < 0.001) and propensity-matched cohorts (p < 0.001). Late pericardial tamponade occurred significantly more frequently in the non-PP group in the overall (p = 0.03) and propensity-matched cohorts (p = 0.03). Total hospitalization costs did not differ between the PP and non-PP groups.

Comparison between the POAF and non-POAF groups

POAF developed in 88 patients (43.7%). The average time to onset of AF was 3.5±3.8 days (median, 2.5 days; range, 0-30 days) after surgery. Progress after POAF was as follows: natural reversion to sinus rhythm in 33 patients, administration of antiarrhythmic drugs in 45 patients, cardioversion in 5 patients, implantation of permanent pacemaker in 3 patients, and ablation in 2 patients. At discharge, sinus rhythm was maintained in 85 patients (96.5%). Univariate analysis identified differences in preoperative characteristics (Table 4), intraoperative data, and postoperative outcomes (Table 5) in patients with and without POAF. Age was significantly higher in the POAF group (p < 0.001), the POAF group included significantly more cases of hyperlipidemia, and the Japan score and Euro score were also higher in the POAF group. The two groups showed no significant difference in stroke (p = 0.9). PP had no significant effect on the occurrence of POAF (p = 0.38). The POAF group showed a significantly longer length of ICU stay (p = 0.003) and hospital stay (p = 0.03). The amounts of pericardial and mediastinal drainage were significantly higher in the POAF group. In addition, the durations of indwelling of the pericardial and mediastinal drains were significantly longer in the POAF group. The CRP level was significantly higher in the POAF group (p = 0.03). Total hospitalization costs did not differ between the POAF and non-POAF groups.

Examination of risk factors for POAF

Multivariate analysis identified older age as an independent predictor of POAF (Table 6).

Discussion

Although the etiology of POAF is not completely understood, various stimuli and triggers such as pre-existing structural changes of the atria related to hypertension, mechanical damage, volume overload, age, intraoperative atrial ischemia, electrolyte imbalance, and pericardial lesions are believed to play a role in its pathogenesis [17-19]. Greenberg et al. [2] pointed out the interplay between pre-existing physiological components, and local and systemic inflammation. In local inflammation, especially, postoperative pericardial fluid is highly oxidative and contains blood, hemolyzed blood cells, hemoglobin, and high levels of inflammatory markers that causes leukocyte and platelet activation, contact between those inflammatory cells and cardiac tissue likely plays a role in the pathogenesis of POAF [20].

The incidence of POAF after cardiovascular surgery is reported in 20-40% of cases [1-4], but most of these cases were reported post-CABG and a few were reported post-thoracic aortic surgery [5, 6]. Matsuura et al. [5] reported that the incidence of POAF after aortic arch repair was 52.7%. In previous reports, the incidence of POAF after thoracic aortic surgery were higher than that after CABG. In our study, the incidence of POAF was as high as 45.6%. This may be due to the fact that we defined AF as an AF episode of 30 s or longer, which was stricter than the definitions used in other studies. Nishi et al. [17] reported that aortic surgery was associated with an almost threefold increase in the risk of POAF, and the incidence of AF was higher in patients undergoing thoracic surgery than in those undergoing other types of cardiac surgery. Sharifov et al. [21] noted that in animal models, the aortic fat pad and vagal tone were associated with the incidence of AF. Thoracic aortic open surgery results in removal of the aortic fat pad and reduction of vagal tone, and this may cause an increase in POAF. Matsuura et al. [5] also reported that POAF after aortic arch repair was associated with prolonged ICU and postoperative hospital stay. In another study, Almassi et al. [7] concluded that POAF after CABG was associated with a higher in-hospital cost of care. Recently, Eikelboom et al. [4] showed that patients who developed POAF after cardiac surgical intervention had an increased risk of death and stroke at 1 year or more after their operation. Therefore, prevention of POAF is a very important issue.

Mulay et al. [8] demonstrated a reduction in both pericardial effusion and related supraventricular arrhythmias with PP. Since then, there have been conflicting reports on the efficacy of PP for POAF [7-13,22-24]. PP provides an effective pathway for drainage of pericardial effusion, which has the above-mentioned inflammatory-inducing components, to the pleural cavity. Blood drainage from the pericardial space by maintaining drain patency in the early hours after surgery may reduce the incidence of POAF and other postoperative complications [2, 25]. There is no study of POAF-reduction effect of PP alone in the thoracic aortic surgery cohort, and we have been performing PP to reduce the incidence of POAF in thoracic aortic surgery since 2018. Nevertheless, in our study, PP had no significant effect on POAF or postoperative stroke reduction. However, it did result in significant reductions in the postoperative mechanical ventilation duration, length of ICU stay, and length of hospital stay. Furthermore, the durations of indwelling of the pericardial and mediastinal drains were significantly shorter in the PP group, and late left pleural drainage occurred significantly more frequently in the non-PP group. Also, the amount of drainage in the pericardial and mediastinal drains was lower in the PP group, and late pericardial tamponade occurred more frequently in the non-PP group. Thus, in our study, PP may bring various benefits by inducing pericardial and mediastinal effusions into the left pleural cavity. In other words, the excretion of inflammatory cells from the pericardium and mediastinum may have had a positive effect. Also, in this study, the incidence of POAF was not lowered by the PP, even though PP could decrease the total amount of the postoperative pericardial and mediastinal drainage. However, the sub-analysis showed that the amount of those drainages were significantly higher in the POAF group than in non-POAF group. There is no clear answer that explain this discrepancy, and further studies are required.

Notably, the mechanical ventilation duration after surgery was reduced in the PP group. However, whether PP reduces the mechanical ventilation duration after surgery remains unclear. Balzer et al. [26] reported that retention of blood around the heart and lungs was associated with ventilation duration after cardiac surgery. From our findings, we cannot confirm whether PP will reduce postoperative mechanical ventilation duration after thoracic aortic surgery. It has also been reported that ventilation hours are reduced by maintaining drain patency and drainage of pericardial effusion and pleural effusion [25]. Therefore, PP may have a beneficial effect on mechanical ventilation management. In our study, there were no difference in the anesthetic drugs used during the operation between the non-PP group and the PP group (Supplemental Table 1). Therefore, intraoperative anesthetic drugs do not affect mechanical ventilation duration after surgery. However, a total of nine cardiovascular surgeons were engaged in postoperative management, which may have affected postoperative mechanical ventilation duration.

In general, the risk factors for POAF after cardiovascular surgery can be summarized as follows: advanced age, male sex, obesity, greater body surface area, hypertension, left atrial enlargement and left ventricular dysfunction, obstructive pulmonary disease, high cholesterol levels, hyperthyroidism, chronic kidney disease, diabetes, history of smoking, preoperative non-use of beta-blockers, prior episodes of AF or electrophysiological abnormalities, surgery for valvular heart disease or aortic disease, urgent operation, transfusion, and postoperative complications (stroke, infections, and unstable hemodynamics) [1, 2, 5, 17, 21, 27]. In particular, advanced age has been identified in most reports and was also a risk factor in our study. Age-related structural changes in the atria, such as increased fibrosis, dilatation, and muscle atrophy, may be associated with the incidence of AF [28]. Moreover, Aviles et al. [29] found out that the CRP level was associated with the presence of AF. However, in our study, CRP level was not associated with POAF after thoracic aortic surgery. As mentioned in the pathogenesis of POAF, systemic inflammation may be associated with POAF.

In this study, no complications were observed with PP, as pointed out by Yorgancioğlu et al. [30]. Thus, PP is a simple and safe technique.

Limitations

The present study was limited by its retrospective, single-center design. Furthermore, the small number of cases made it difficult to draw a clear conclusion. For instance, PP showed no significant effects on POAF reduction. Large cohort studies with a large number of cases may provide significant results in this regard.

Conclusions

PP has no effect on reducing POAF after thoracic aortic surgery. PP reduces the occurrence of late pericardial tamponade, the length of ICU stay, length of hospital stay, and mechanical ventilation duration after surgery by suppressing local and systemic inflammation. However, a large cohort study is needed to clarify the effects of PP.

Abbreviations

POAF: postoperative atrial fibrillation

AF: atrial fibrillation

CABG: coronary artery bypass grafting

AVR: aortic valve replacement

PP: posterior pericardiotomy

CPB: cardiopulmonary bypass

FET: frozen elephant trunk

ICU: intensive care unit

ECG: electrocardiogram

WBC: white blood cell

CRP: C-reactive protein

eGFR: estimated glomerular rate

ACEI: angiotensin converting enzyme inhibitor

ARB: angiotensin receptor blocker

LVEF: left ventricular ejection fraction

LAD: left atrial dimension

TAR: total arch replacement

RRT: renal replacement therapy

Declarations

Ethics approval and consent to participate

This study was approved by the ‘Institutional Review Board for Observation and Epidemiological Study’ of Ise Red Cross Hospital, and all participants provided informed consent.

All methods were performed in accordance with the relevant guidelines and regulations.

Consent for publication

The patients gave permission for the publication of this study.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding

The authors received no specific funding for this work.

Authors’ contributions

YM designed the study and wrote the initial draft of the manuscript. YM, TT and HI contributed to the analysis and interpretation of the data and assisted in the preparation of the manuscript. MM, DY, RI, KH and BN contributed to the clinical management of the patients. YM and TT performed the surgery of the patients. YM and TT revised the manuscript critically and approved the modified text. All authors read and approved the final manuscript.

Acknowledgement

Not applicable.

References

1. Phan K, Ha HSK, Phan S, Medi C, Thomas SP, Yan TD. New-onset atrial fibrillation following coronary bypass surgery predicts long-term mortality: a systematic review and meta-analysis. Eur J Cardiothorac Surg. 2015; 48:817–24. https://doi.org/10.1093/ejcts/ezu551
2. Greenberg JW, Lancaster TS, Schuessler RB, Melby SJ. Postoperative atrial fibrillation following cardiac surgery: a persistent complication. Eur J Cardiothorac Surg. 2017; 52:665–72. https://doi.org/10.1093/ejcts/ezx039
3. Shahim B, Malaisrie SC, George I, Thourani VH, Biviano AB, Russo M, et al. Postoperative atrial fibrillation or flutter following transcatheter or surgical aortic valve replacement: PARTNER 3 Trial. JACC Cardiovasc Interv. 2021;14:1565–74. https://doi.org/10.1016/j.jcin.2021.05.026
4. Eikelboom R, Sanjanwala R, Le ML, Yamashita MH, Arora RC. Postoperative atrial fibrillation after cardiac surgery: a systematic review and meta-analysis. Ann Thorac Surg. 2021;111:544–54. https://doi.org/10.1016/j.athoracsur.2020.05.104
5. Matsuura K, Ogino H, Matsuda H, Minatoya K, Sasaki H, Kada A, et al. Prediction and incidence of atrial fibrillation after aortic arch repair. Ann Thorac Surg. 2006;81:514–8. https://doi.org/10.1016/j.athoracsur.2005.07.052
6. Arakawa M, Miyata H, Uchida N, Motomura N, Katayama A, Tamura K, et al. Postoperative atrial fibrillation after thoracic aortic surgery. Ann Thorac Surg. 2015;99:103–8. https://doi.org/10.1016/j.athoracsur.2014.08.019
7. Almassi GH, Wagner TH, Carr B, Hattler B, Collins JF, Quin JA, et al. Postoperative atrial fibrillation impacts on costs and one-year clinical outcomes: the Veterans Affairs randomized on/off bypass trial. Ann Thorac Surg. 2015;99:109–14. https://doi.org/10.1016/j.athoracsur.2014.07.035
8. Mulay A, Kirk AJ, Angelini GD, Wisheart JD, Hutter JA. Posterior pericardiotomy reduces the incidence of supra-ventricular arrhythmias following coronary artery bypass surgery. Eur J Cardiothorac Surg. 1995;9:150–2. https://doi.org/10.1016/s1010-7940(05)80063-6
9. Farsak B, Günaydin S, Tokmakoǵlu H, Kandemir O, Yorgancioǵlu C, Zorlutuna Y. Posterior pericardiotomy reduces the incidence of supra-ventricular arrhythmias and pericardial effusion after coronary artery bypass grafting. Eur J Cardiothorac Surg. 2002;22:278–81. https://doi.org/10.1016/s1010-7940(02)00259-2
10. Fawzy H, Elatafy E, Elkassas M, Elsarawy E, Morsy A, Fawzy A. Can posterior pericardiotomy reduce the incidence of postoperative atrial fibrillation after coronary artery bypass grafting?. Interact Cardiovasc Thorac Surg. 2015;21:488–91. https://doi.org/10.1093/icvts/ivv190
11. Gozdek M, Pawliszak W, Hagner W, Zalewski P, Kowalewski J, Paparella D, et al. Systematic review and meta-analysis of randomized controlled trials assessing safety and efficacy of posterior

pericardial drainage in patients undergoing heart surgery. J Thorac Cardiovasc Surg. 2017;153:865–75.e12. https://doi.org/10.1016/j.jtcvs.2016.11.057

12. Xiong T, Pu L, Ma YF, Zhu YL, Li H, Cui X, et al. Posterior pericardiotomy to prevent new-onset atrial fibrillation after coronary artery bypass grafting: a systematic review and meta-analysis of 10 randomized controlled trials. J Cardiothorac Surg. 2021;16:233. https://doi.org/10.1186/s13019-021-01611-x
13. Gaudino M, Sanna T, Ballman KV, Robinson NB, Hameed I, Audisio K, et al. Posterior left pericardiotomy for the prevention of atrial fibrillation after cardiac surgery: an adaptive, single-centre, single-blind, randomised, controlled trial. Lancet. 2021;398:2075–83. https://doi.org/10.1016/S0140-6736(21)02490-9
14. van Swieten JC, Koudstaal PJ, Visser MC, Schouten HJA, van Gijn J. Interobserver agreement for the assessment of handicap in stroke patients. Stroke. 1988;19:604–7. https://doi.org/10.1161/01.str.19.5.604
15. Calkins H, Hindricks G, Cappato R, Kim YH, Saad EB, Aguinaga L, et al. 2017 HRS/EHRA/ECAS/APHRS/SOLAECE expert consensus statement on catheter and surgical ablation of atrial fibrillation. Heart Rhythm. 2017;14:e275–e444. https://doi.org/10.1016/j.hrthm.2017.05.012
16. Kanda Y. Investigation of the freely available easy-to-use software ‘EZR’ for medical statistics. Bone Marrow Transplant. 2013;48: 452–8. https://doi.org/10.1038/bmt.2012.244
17. Nishi H, Sakaguchi T, Miyagawa S, Yoshikawa Y, Fukushima S, Saito S, et al. Atrial fibrillation occurring early after cardiovascular surgery: impact of the surgical procedure. Surg Today. 2013;43:1134–39. https://doi.org/10.1007/s00595-012-0372-9
18. Aranki SF, Shaw DP, Adams DH, Rizzo RJ, Couper GS, VanderVliet M, et al. Predictors of atrial fibrillation after coronary artery surgery. Current trends and impact on hospital resources. Circulation. 1996;94:390–7. https://doi.org/10.1161/01.cir.94.3.390
19. Biancari F, Mahar MAA. Meta-analysis of randomized trials on the efficacy of posterior pericardiotomy in preventing atrial fibrillation after coronary artery bypass surgery. J Thorac Cardiovasc Surg. 2010;139:1158–61. https://doi.org/10.1016/j.jtcvs.2009.07.012
20. Kramer PA, Chacko BK, Ravi S, Johnson MS, Mitchell T, Barnes S, et al. Hemoglobin-associated oxidative stress in the pericardial compartment of postoperative cardiac surgery patients. Lab Invest. 2015;95:132–41. https://doi.org/10.1038/labinvest.2014.144
21. Sharifov OF, Zaitsev AV, Rosenshtraukh LV, Kaliadin AY, Beloshapko GG, Yushmanova AV, et al. Spatial distribution and frequency dependence of arrhythmogenic vagal effects in canine atria. J Cardiovasc Electrophysiol. 2000;11:1029–42. https://doi.org/10.1111/j.1540-8167.2000.tb00176.x
22. Asimakopoulos G, Della Santa R, Taggart DP. Effects of posterior pericardiotomy on the incidence of atrial fibrillation and chest drainage after coronary revascularization: a prospective randomized trial. J Thorac Cardiovasc Surg. 1997;113:797–9. https://doi.org/10.1016/s0022-5223(97)70242-3
23. Haddadzadeh M, Motavaselian M, Rahimianfar AA, Forouzannia SK, Emami M, Barzegar K. The effect of posterior pericardiotomy on pericardial effusion and atrial fibrillation after off-pump

coronary artery bypass graft. Acta Med Iran. 2015;53:57–61

24. Kongmalai P, Karunasumetta C, Kuptarnond C, Prathanee S, Taksinachanekij S, Intanoo W, et al. The posterior pericardiotomy. Does it reduce the incidence of postoperative atrial fibrillation after coronary artery bypass grafting? J Med Assoc Thai. 2014;97;Suppl 10:S97–S104
25. Sirch J, Ledwon M, Püski T, Boyle EM, Pfeiffer S, Fischlein T. Active clearance of chest drainage catheters reduces retained blood. J Thorac Cardiovasc Surg. 2016;151:832–838.e2. https://doi.org/10.1016/j.jtcvs.2015.10.015
26. Balzer F, von Heymann C, Boyle EM, Wernecke KD, Grubitzsch H, Sander M. Impact of retained blood requiring reintervention on outcomes after cardiac surgery. J Thorac Cardiovasc Surg. 2016;152:595–601.e4. https://doi.org/10.1016/j.jtcvs.2016.03.086
27. Mathew JP, Fontes ML, Tudor IC, Ramsay J, Duke P, Mazer CD, et al. A multicenter risk index for atrial fibrillation after cardiac surgery. JAMA. 2004;291:1720–9. https://doi.org/10.1001/jama.291.14.1720
28. Ommen SR, Odell JA, Stanton MS. Atrial arrhythmias after cardiothoracic surgery. N Engl J Med. 1997;336:1429–34. https://doi.org/10.1056/NEJM199705153362006
29. Aviles RJ, Martin DO, Apperson-Hansen C, Houghtaling PL, Rautaharju P, Kronmal RA, et al. Inflammation as a risk factor for atrial fibrillation. Circulation. 2003;108:3006–10. https://doi.org/10.1161/01.CIR.0000103131.70301.4F
30. Yorgancioğlu C, Farsak B, Tokmakoğlu H, Günaydin S. An unusual experience with posterior pericardiotomy. Eur J Cardiothorac Surg. 2000;18:727–8. https://doi.org/10.1016/s1010-7940(00)00586-8

Tables

Tables 1 to 6 are available in the Supplementary Files section.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Table1.docx
- Table2.docx
- Table3.docx
- Table4.docx
- Table5.docx
- Table6.docx
- SupplementalTable1.docx