Investigation of the effect of postoperative early-term high-flow oxygen use on new-onset atrial fibrillation in high-risk patient groups after isolated coronary artery bypass graft operations

F. ATA[1], M. ENGIN[2]

[1]Department of Anesthesiology and Reanimation, [2]Department of Cardiovascular Surgery, University of Health Sciences, Bursa Yuksek Ihtisas Training and Research Hospital, Bursa, Turkey

Abstract. – OBJECTIVE: Postoperative atrial fibrillation (PoAF) is a significant complication that may occur after coronary artery bypass graft (CABG) surgeries. High-flow nasal oxygen (HFNO) therapy has recently been used in adult patients. In this current study, we aimed to investigate the effect of early HFNO treatment after extubation on the development of postoperative atrial fibrillation, in patient groups at risk for PoAF.

PATIENTS AND METHODS: Patients who underwent isolated CABG surgery in our clinic between October 2021 and January 2022 and had a preoperative HATCH score of above 2, were retrospectively included in this study. After the extubation, patients who were followed-up with HFNO were defined as Group 1, and patients who were followed-up with a standard oxygen treatment were determined as Group 2.

RESULTS: Group 1 consisted of thirty-seven patients with a median age of 56 (ranging between 37 and 75) years, while Group 2 had seventy-one patients with a median age of 58 (ranging between 41 and 71) years (p=0.357). The groups were similar in terms of gender, hypertension, diabetes mellitus, hypercholesterolemia, smoking, body mass index, and ejection fraction. The need for positive inotropic support and incidence of PoAF was significantly higher in Group 2 (p=0.022, p=0.017, respectively).

CONCLUSIONS: In this study, we showed that HFNO treatment can reduce the rates of PoAF in high-risk patient groups.

Key Words:
Coronary artery bypass grafting, Endotracheal extubation, Oxygen therapy, Atrial fibrillation.

Introduction

Postoperative atrial fibrillation (PoAF) is a significant complication that may occur after coronary artery bypass graft (CABG) surgeries. PoAF increases the cost of treatment by prolonging hospitalization, and it may result in serious outcomes such as cerebrovascular accidents and heart failure[1]. For this reason, it is imperative to identify risky groups for PoAF and take necessary precautions.

The HATCH score is a scoring system that includes known risk factors for atrial fibrillation such as heart failure, advanced age, history of cerebrovascular accidents, hypertension, and chronic obstructive pulmonary disease (COPD)[2]. The scores range between 0 and 7 points, and results above 2 is an important risk factor for PoAF[3]. Respiratory difficulties in the postoperative period constitute an important problem for PoAF. High-flow nasal oxygen (HFNO) therapy, which is an important non-invasive treatment method in pediatric Intensive Care Units, has recently been used in adult patients as well[4,5]. In one study[6], it was shown that the use of HFNO in the early postoperative period in obese cardiac surgery patients reduced respiratory complications.

In this current study, we aimed to investigate the effect of early HFNO treatment after extubation on the development of postoperative atrial fibrillation, in patient groups at risk for PoAF (HATCH score >2).

Patients and Methods

Patients who underwent isolated CABG surgery in our clinic between October 2021 and January 2022 and had a preoperative HATCH score of above 2, were retrospectively included in this study. The study was initiated after the approval of the Bursa Yuksek Ihtisas Training

Corresponding Author: Mesut Engin, MD; e-mail: mesut_kvc_cor@hotmail.com

and Research Hospital Clinical Research Ethics Committee and conducted in accordance with the Helsinki Declaration. Patients requiring additional cardiac surgical procedures, emergency operations, patients with known atrial fibrillation, those with thyroid dysfunction, those with a left atrial diameter greater than 50 mm, and patients receiving preoperative amiodarone therapy, were all excluded from the study. As a result of the exclusion criteria, 108 consecutive patients were included and their data were obtained from the intensive care daily follow-up cards and patient files. Preoperative characteristics (age, gender, additional disease assets such as hypertension, current medical treatments, etc.), operative characteristics (Perfusion times, number of coronary bypasses), and postoperative characteristics (PoAF status, Intensive Care Unit length of stay) of all patients were recorded.

In our Intensive Care Unit (ICU), we were able to apply an HFNO treatment to thirty-seven of the patients in the early postoperative period, which were defined as Group 1. The patients who were followed up with a standard 2-4L/min nasal oxygen cannula or 6 L/min face mask after extubation, were determined as Group 2.

HFNO Treatment

In our patient group, humidified and heated oxygen at a flow rate of 30-60 L/min after extubation was administered with a nasal cannula using a high-flow oxygen therapy device (Fisher & Paykel myAirvo 2, Sapio Life, Turkey). Patients were provided with non-invasive respiratory support by administering heated, humidified, oxygen-enriched air. Compared to standard oxygen therapy, the oxygenation-correcting effect of high-flow nasal oxygen therapy begins when the flow is above 30 L min-1 and reaches maximum efficiency at 60 L min-1. Depending on the rate of the adjusted flow, a positive pressure of 5-6 cm H_2O occurs in patients, which has an effect similar to positive end-expiratory pressure in the airway[4,5].

Diagnosis of PoAF

In the ICU, all patients were observed with continuous heart rhythm and invasive blood pressure monitoring. In addition, daily 12-lead electrocardiography (ECG) was taken during the hospital stay when the patients expressed complaints such as palpitation, dyspnea, or angina pectoris. Atrial fibrillation was verified *via* the 12-lead ECG and the diagnosis of AF was based on the guidelines of the European Society of Cardiology[7]. PoAF was defined as irregular or fibrillatory waves in place of typical P waves on ECG. An AF episode >60 s was accepted as a PoAF.

Statistical Analysis

Statistical analysis was performed using the SPSS 21.0 (Statistical Package for the Social Sciences Statistic, IBM Corp., Armonk, NY, USA). The normality distribution of data was analyzed using the Kolmogorov-Smirnov and Shapiro-Wilk tests. The student's *t*-test was utilized for normally distributed data (mean and standard deviation) and the Mann-Whitney U test was used for non-normally distributed data (median and minimum-maximum). Nominal variables were expressed in frequency and percentage and the Chi-Square test was utilized for analysis. A univariate and multivariate logistic regression analysis was performed to analyze the factors affecting the development of PoAF. The univariate logistic regression analysis was utilized initially, then variables associated with a p-value ≤ 0.20 in univariate analyses were considered for inclusion in the multivariate analyses (parameters not included in the HATCH score since the HATCH score was included). A p-value <.05 was considered significant.

Results

The baseline demographic and clinical features of the patients are presented in Table I. Group 1 consisted of thirty-seven patients with a median age of 56 (ranging between 37 and 75) years, while Group 2 had seventy-one patients with a median age of 58 (ranging between 41 and 71) years (p=0.357). The groups were similar in terms of gender, hypertension, diabetes mellitus, hypercholesterolemia, smoking, body mass index, ejection fraction, and current medical treatments (such as angiotensin-converting enzyme inhibitors, angiotensin receptor blockers, and beta-blocker therapy). The preoperative laboratory parameters are presented in Table I. There were no significant differences between the groups in terms of white blood cell (WBC), hematocrit (Hct), platelet counts, urea, and creatinine values. C-Reactive protein value was significantly higher in Group 2 (p=0.008).

The operative and postoperative features of the patients are presented in Table II. Perfusion times, the number of distal anastomoses, total drainage

Table I. Demographic and preoperative features of the patients.

Variables	Group 1 (N= 37)	Group 2 (N= 71)	*p*-value
Age (years)	56 (37-75)	58 (41-71)	0.357‡
Male gender, n (%)	26 (70.3%)	54 (76.1%)	0.515*
Hypertension, n (%)	22 (59.5%)	45 (63.4%)	0.690*
Diabetes mellitus, n (%)	10 (27%)	23 (32.4%)	0.566*
Hypercholesterolemia, n (%)	19 (51.4%)	47 (66.2%)	0.133*
Current smoker, n (%)	15 (40.5%)	36 (50.7%)	0.315*
COPD, n (%)	8 (21.6%)	19 (26.8%)	0.558*
Previous CVA	4 (10.8%)	10 (14.1%)	0.631*
BMI (kg/m2)	27.4 (25-37.2)	26.9 (26-45.1)	0.294‡
Ejection fraction (%)	50 (30-60)	50 (35-65)	0.209‡
β-Blocker therapy, n (%)	29 (78.4%)	62 (87.3%)	0.226*
ARB/ACE-I therapy, n (%)	9 (24.3%)	16 (22.5%)	0.834*
Left atrial diameter, mm	29 (24-48)	30 (24-46)	0.198‡
White blood Cell (103/μL)	8.1 (4.9-11.2)	7.9 (5-12.3)	0.215‡
Platelet (103/μL)	225 (144-380)	233 (130-373)	0.314‡
Hematocrit (%)	39 (35-51)	42 (33-48)	0.472‡
Creatinine, mg/dL	0.92 (0.8-2)	0.94 (0.7-2)	0.712‡
Urea, mg/dL	20 (16-44)	22 (14-40)	0.092‡
C-Reactive protein (mg/dL)	7.9 (0.5-33)	9 (0.6-27)	0.008‡

*Chi-square test, ‡Mann-Whitney U test [Data is expressed as median (minimum-maximum)], ACE-I, angiotensin-converting enzyme inhibitor; ARB, angiotensin receptor blocker BMI: Body mass index, CVA: Cerebrovascular accident; COPD: Chronic obstructive pulmonary disease.

amounts, and hospital stays were statistically similar between the two groups. The need of positive inotropic support and incidence of PoAF was significantly higher in Group 2 (p=0.022, p=0.017, respectively).

Logistic regression analysis was performed to predict the factors affecting the development of PoAF (Table III). In the univariate analysis, PoAF was found to significantly correlate with age >70 years [odds ratio (OR): 1.826, 95% confidence interval (CI): 1.195-2.794, p<0.001], EF <35% (OR: 1.226, 95% CI: 1.090-2.155, p=0.018), hypertension (OR: 0.690, 95% CI: 0.315-0.836, p=0.041), COPD (OR: 0.312, 95% CI: 0.145-0.976, p=0.034), C-reactive protein (OR: 0.810, 95% CI: 0.449-0.962, p=0.042), need of inotropic support (OR: 0.241, 95% CI: 0.066-0.841, p=0.031), HATCH score >4 (OR: 3.190, 95% CI: 1.785-5.870, p<0.001), and HFNO treatment (OR: 0.336, 95% CI: 0.135-0.837, p=0.019). In multivariate analysis, HATCH score >4 (OR: 2.985, 95% CI: 1.620-4.980, p<0.001), and HFNO treatment (OR: 0.298, 95% CI: 0.129-0.794, p=0.041) were determined as independent predictors of PoAF.

Discussion

Atherosclerotic heart disease is a prominent disease, with an inflammatory background. CABG

Table II. Operative and postoperative features of the patients.

Variables	Group 1 (N= 37)	Group 2 (N= 71)	*p*-value
Total perfusion time	90 (55-180)	94 (50-168)	0.114‡
Cross-clamp time	55 (38-95)	60 (30-90)	0.282‡
Number of distal anastomoses	3 (2-6)	3 (2-6)	0.694‡
Total chest tube drainage (ml)	800 (300-1,900)	900 (400-1,700)	0.169‡
Packed blood products (units)	3.9±1.5	4±1.6	0.134‡
Inotropic support, n (%)	3 (8.1%)	19 (26.7%)	0.022*
Total ICU stay (days)	2 (2-4)	2 (2-4)	0.834‡
PoAF, n (%)	8 (21.6%)	32 (45.1%)	0.017*

*Chi-square test, ‡Mann-Whitney U test; ICU: Intensive care unit; PoAF: Postoperative atrial fibrillation.

Table III. Logistic regression analysis to identify factors affecting the development of postoperative atrial fibrillation.

	Univariate analysis			Multivariate analysis		
Variables	***p***	**Exp (B) Odds Ratio**	**95% CI Lower Upper**	***p***	**Exp (B) Odds Ratio**	**95% CI Lower Upper**
Age>70	<0.001	1.826	1.195-2.794	--	--	--
EF <35%	0.018	1.226	1.090-2.155	--	--	--
Hypertension	0.041	0.690	0.315-0.836	--	--	--
Diabetes Mellitus	0.156	1.084	0.775-1.190	--	--	--
COPD	0.034	0.312	0.145-0.976	--	--	--
C-Reactive protein	0.042	0.810	0.449-0.962	--	--	--
Total perfusion time	0.090	1.040	0.930-1.448	--	--	--
Inotropic support	0.031	0.241	0.066-0.841	0.194	0.790	0.584-1.110
HATCH score >4	<0.001	3.190	1.785-5.870	<0.001	2.985	1.620-4.980
HFNO treatment (None)	0.019	0.336	0.135-0.837	0.041	0.298	0.129-0.794

COPD: Chronic obstructive pulmonary disease, EF: Ejection fraction, HFNO: High-flow nasal oxygen.

surgeries have been performed safely for years in the treatment of this disease. PoAF is a significant complication that may occur after these operations and can cause various mortal and morbid problems. Many studies[3,8] investigating PoAF risk factors and preventive factors have been conducted in the literature. In this current study and to the best of our knowledge for the first time in the literature, we investigated the protective effect of HFNO treatment in patients at risk for PoAF and who underwent isolated CABG surgeries. We found that applying HFNO therapy after extubation compared to standard oxygen therapy reduced the rates of PoAF.

Advanced age, impaired ventricular function, and diseases such as COPD, are known risk factors that increase the probability of PoAF. The HATCH score, including these parameters, and other scoring systems have been used in various studies[3,9,10] to predict the risk of atrial fibrillation. Advanced age is generally accepted as a factor that increases the risk of postoperative complications in all adult surgical procedures. Fibrosis in cardiac conduction pathways also increases with increasing age and the risk of AF increases as well, as a result of the increased accumulation of collagen debris in the atrial structures[11]. The presence of hypertension (HT) is also an important risk factor for PoAF. Stress on vascular structures increases in patients with HT, which may increase the risk for PoAF by triggering inflammatory processes[12]. In patients with low ejection function, the risk of AF increases as the heart chambers dilate[13]. A history of cerebrovascular events is also known as a risk factor for PoAF, as it may result from a possible AF attack, as well as indicating an inflammatory condition[14]. COPD is also an inflammatory disease and it is an accepted risk factor for PoAF, as additional respiratory problems occur postoperatively in these patients[15]. The HATCH score was created to evaluate the combination of all these factors. Studies[2,3] in the literature have shown that it increases the risk of AF in the general population and during the postoperative period. In light of this information, we included patients with a HATCH score above 2 in our study and determined that a HATCH score >4 was an independent predictor for PoAF.

High-flow nasal oxygen therapy has been used in the treatment of adult acute hypoxemic respiratory failure since the beginning of the 21st century. Studies[16,17] conducted in the interim have shown that it is equivalent to non-invasive mechanical ventilation. HFNO treatment has considerable beneficial effects, such as reducing resistance by clearing the nasopharyngeal dead space, moisturizing the airways, improving mucociliary clearance, and increasing the inspired oxygen fraction[18]. The FLORALI (High flow oxygen therapy for resuscitation of patients with acute lung injury) study[16] was a randomized controlled trial, in which HFNO, standard oxygen therapy, and non-invasive mechanical ventilation therapy were compared in patients with various respiratory failures. There was no difference between the three groups in terms of intubation rates. However, in post hoc analyses of 238 patients with severe hypoxemia ($PaO_2/FiO_2 \leq 200$ mmHg) at baseline, the intubation rate was found to be significantly lower in the HFNO group compared to the other groups (p=0.009). In addition, when the entire patient cohort was evaluated, it was revealed[16] that it reduced the 90-day mortality.

In literature, the cardiac surgical use of HFNO therapy is widely discussed. In the study conducted by Parke et al[19], the effects of HFNO treatment in the first 48 hours after cardiac surgery were investigated. In this study, which included 340 patients, it was shown that HFNO treatment did not affect oxygen values, though it was shown to reduce the need for respirators. At the end of their study, the authors concluded that it is not necessary to use routine HFNO after uncomplicated cardiac surgical operations. In another study[20] conducted in the following years, the effect of HFNO use in patients with hypoxemia after cardiac surgery was investigated. In that study, in which 82 patients were randomized, it was shown that HFNO treatment reduced twofold the need for non-invasive mechanical ventilation. The authors[20] emphasized that HFNO therapy can be used in post-cardiac surgical patients with hypoxemia. In a recent article published by Theologou et al[21] in 2021, the importance of HFNO treatment in post-extubation hypoxemia was investigated. In the study, which included 99 individuals, patients were divided into three groups [intervention group 1 [High-flow nasal cannula (HFNC) initial flow = 60 L/min, $FiO_2 = 0.6$], intervention group 2 (HFNC initial flow = 40 L/min, $FiO_2 = 0.6$), or control group (Venturi mask, $FiO_2 = 0.6$).] Although HFNO treatment was found to be more effective than the conventional method, HFNC flow of 60 L/min treatment was found to be more effective in terms of respiratory parameters[21].

The presence of obesity can lead to various problems after cardiac surgery and respiratory problems are among these. In a study by Corley et al[6], the effectiveness of early HFNO treatment after cardiac surgery was investigated in patients with body mass index (BMI) >30 kg/m^2. At the end of this study, which included 155 patients, the authors found that HFNO treatment did not lead to an improvement in respiratory functions. In the following years, a similar study was carried out by Sahin et al[22]. One hundred patients were included in this study comparing HFNO and standard oxygen masks after cardiopulmonary bypass in obese patients. Unlike the previous study[6], the authors demonstrated that HFNO treatment provided improvement in respiratory functions, reduction in atelectasis scores, and reduction in reintubation rates. In our study, we showed that HFNO treatment in the first 48 hours after isolated CABG surgeries can reduce the rates of PoAF in the patient group at risk for PoAF.

Limitations

The most important limitations of our study are that it is a single-center and retrospective study. There is a need for new prospective multicenter studies in this area.

Conclusions

CABG surgeries are the most important treatment option for atherosclerotic heart disease. Atrial fibrillation, which has newly emerged after these procedures, is an important problem. For this reason, much research is conducted on PoAF risk factors and preventive measures: in this study, we showed that HFNO treatment can reduce the rates of PoAF in high-risk patient groups.

Conflict of Interest
The Authors declare that they have no conflict of interests.

Acknowledgments
None.

Ethics Approval
The Internal Review Board approved the study protocol at the Bursa Yuksek Ihtisas Training and Research Hospital Clinical Research Ethics Committee (Protocol number: 2011-KAEK- 25 2022/08-14).

Informed Consent
Not applicable due to the retrospective nature of the study.

Funding
None.

Authors' Contribution
All authors contributed to: conception and design, or acquisition of data, analysis and interpretation of data, drafting the article or revising it critically for important intellectual content, and final approval of the version to be published.

Availability of Data and Materials
The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

ORCID ID
F. Ata: 0000-0003-2472-1681.
M. Engin: 0000-0003-2418-5823.

References

1) Katlandur H, Özbek K, Özdil H, Arık B, Kuzgun A, Keser A, Ulucan S, Sıddık Ülgen M. Total pulmonary vein diameter is a strong predictor of atrial fibrillation after coronary artery bypass graft surgery. Eur Rev Med Pharmacol Sci 2016; 20: 1327-1332.
2) Cay S, Kara M, Ozcan F, Ozeke O, Korkmaz A, Cetin H, Aksu T, Topaloglu S. A new scoring system: PAT2C2H score. Its clinical use and comparison with HATCH and CHA2DS2-VASc scores in predicting arrhythmia recurrence after cryoballoon ablation of paroxysmal atrial fibrillation. J Interv Card Electrophysiol 2022. Epub ahead of print doi: 10.1007/s10840-022-01328-4.
3) Engin M, Aydın C. Investigation of the Effect of HATCH Score and Coronary Artery Disease Complexity on Atrial Fibrillation after On-Pump Coronary Artery Bypass Graft Surgery. Med Princ Pract 2021; 30: 45-51.
4) Çaparlar CÖ, Uyar BS. High Flow Nasal Oxygenation and Indications. JARSS 2021; 29: 211-218.
5) Mauri T, Alban L, Turrini C, Cambiaghi B, Carlesso E, Taccone P, Bottino N, Lissoni A, Spadaro S, Volta CA, Gattinoni L, Pesenti A, Grasselli G. Optimum support by high-flow nasal cannula in acute hypoxemic respiratory failure: effects of increasing flow rates. Intensive Care Med 2017; 43: 1453-1463.
6) Corley A, Bull T, Spooner AJ, Barnett AG, Fraser JF. Direct extubation onto high-flow nasal cannulae post-cardiac surgery versus standard treatment in patients with a BMI ≥30: a randomized controlled trial. Intensive Care Med 2015; 41: 887-894.
7) Savran M, Engin M, Guvenc O, Yüksek HF, Sünbül SA, Turk T, Ata Y, Aydın U, Ozyazicioglu AF. Predictive Value of HATCH Scoring and Waist-to-Height Ratio in Atrial Fibrillation Following Coronary Artery Bypass Operations Performed with Cardiopulmonary Bypass. J Saudi Heart Assoc 2021; 33: 117-123.
8) Kara H, Yasim A. Effects of high-dose vitamin D supplementation on the occurrence of post-operative atrial fibrillation after coronary artery bypass grafting: randomized controlled trial. Gen Thorac Cardiovasc Surg 2020; 68: 477-484.
9) Kiedrowicz RM, Wielusiński M, Wojtarowicz A, Kaźmierczak J. Atrial fibrillation risk scores to evaluate left atrial substrate based on voltage analysis in long-standing persistent type of arrhythmia. Kardiol Pol 2021; 79: 525-530.
10) Suenari K, Chao TF, Liu CJ, Kihara Y, Chen TJ, Chen SA. Usefulness of HATCH score in the prediction of new-onset atrial fibrillation for Asians. Medicine (Baltimore) 2017; 96: e5597.
11) Echahidi N, Pibarot P, O'Hara G, Mathieu P. Mechanisms, prevention, and treatment of atrial fibrillation after cardiac surgery. J Am Coll Cardiol 2008; 51: 793e801.
12) Hallstrom S, Pivodic A, Rosengren A, Olafsd ottir AF, Svensson AM, Lind M. Risk factors for atrial fibrillation in people with type 1 diabetes: an observational CohortStudy of 36,258 patients from the Swedish national diabetes registry. Diabetes Care 2019; 42: 1530e8.
13) Lardizabal JA, Deedwania PC. Atrial fibrillation in heart failure. Med Clin North Am 2012; 96: 987e1000.
14) Heeringa J, van der Kuip DA, Hofman A, Kors JA, van Rooij FJ, Lip GY, Witteman JC. Subclinical atherosclerosis and risk of atrial fibrillation: the rotterdam study. Arch Intern Med 2007; 167: 382-387.
15) Lopez-Candales A, Rajagopalan N, Dohi K, Gulyasy B, Edelman K, Bazaz R. Abnormal right ventricular myocardial strain generation in mild pulmonary hypertension. Echocardiography 2007; 24: 615e22.
16) Frat JP, Thille AW, Mercat A, Girault C, Ragot S, Perbet S, Prat G, Boulain T, Morawiec E, Cottereau A, Devaquet J, Nseir S, Razazi K, Mira JP, Argaud L, Chakarian JC, Ricard JD, Wittebole X, Chevalier S, Herbland A, Fartoukh M, Constantin JM, Tonnelier JM, Pierrot M, Mathonnet A, Béduneau G, Delétage-Métreau C, Richard JC, Brochard L, Robert R; FLORALI Study Group; REVA Network. High-flow oxygen through nasal cannula in acute hypoxemic respiratory failure. N Engl J Med 2015; 372: 2185-2196.
17) Hernández G, Vaquero C, Colinas L, Cuena R, González P, Canabal A, Sanchez S, Rodriguez ML, Villasclaras A, Fernández R. Effect of Postextubation High-Flow Nasal Cannula vs Noninvasive Ventilation on Reintubation and Postextubation Respiratory Failure in High-Risk Patients: A Randomized Clinical Trial. JAMA 2016; 316: 1565-1574.
18) Sztrymf B, Messika J, Bertrand F, Hurel D, Leon R, Dreyfuss D, Ricard JD. Beneficial effects of humidified high flow nasal oxygen in critical care patients: a prospective pilot study. Intensive Care Med 2011; 37: 1780-1786.
19) Parke R, McGuinness S, Dixon R, Jull A. Open-label, phase II study of routine high-flow nasal oxygen therapy in cardiac surgical patients. Br J Anaesth 2013; 111: 925-931.
20) Vourc'h M, Nicolet J, Volteau C, Caubert L, Chabbert C, Lepoivre T, Senage T, Roussel JC, Rozec B. High-Flow Therapy by Nasal Cannulae Versus High-Flow Face Mask in Severe Hypoxemia After Cardiac Surgery: A Single-Center Randomized Controlled Study-The HEART FLOW Study. J Cardiothorac Vasc Anesth 2020; 34: 157-165.
21) Theologou S, Ischaki E, Zakynthinos SG, Charitos C, Michopanou N, Patsatzis S, Mentzelopoulos SD. High Flow Oxygen Therapy at Two Initial Flow Settings versus Conventional Oxygen Therapy in Cardiac Surgery Patients with Postextubation Hypoxemia: A Single-Center, Unblinded, Randomized, Controlled Trial. J Clin Med 2021; 10: 2079.
22) Sahin M, El H, Akkoç I. Comparison of Mask Oxygen Therapy and High-Flow Oxygen Therapy after Cardiopulmonary Bypass in Obese Patients. Can Respir J 2018; 2018: 1039635.