BMC Anesthesiology

RESEARCH

Open Access

The effect of preoperative deep breathing exercise with incentive spirometer initiated in the preoperative period on respiratory parameters and complications in patients underwent open heart surgery: a randomized controlled trial

Hatice Öner Cengiz[1*], Zeynep Uluşan Özkan[2] and Eylem Gani[2]

Abstract

Background Incentive spirometer is used in lung expansion therapy to maintain alveolar patency and improve pulmonary volumes in postoperative cardiac surgical patients. Deep breathing exercises with an incentive spirometer significantly reduce the development of postoperative pulmonary complications after open-heart cardiac surgery.

Aim To determine the effect of deep breathing exercises with an incentive spirometer initiated in the preoperative period on respiratory parameters and complications in patients who underwent open-heart surgery.

Methods This randomized controlled study was conducted with a total of 66 participants. The participants were randomized into a deep breathing group ($n=32$) and a control group ($n=34$). The control group received hospital routine physiotherapy, and the deep breathing group started to perform deep breathing exercises with an incentive spirometer in the preoperative period. Data were collected with the Sociodemographic and Medical Data Form and Patient Follow-up Form (respiratory rate, oxygen saturation (SpO_2) level, arterial blood gas parameters and posteroanterior chest X-ray were monitored with this form prepared by the investigators). The Medical Research Council Scale was used to determine the severity of dyspnea in the patients included in the study. Primary outcomes included respiratory rate, oxygen saturation, arterial blood gas parameters, posteroanterior chest X-ray, and evaluation of postoperative pulmonary complications development. Secondary outcomes included the mechanical ventilation time, length of intensive care unit stay, and length of hospital stay.

Results The incidence of postoperative pulmonary complications was 3.1% and 23.5% ($p<0.05$) in the deep breathing and control groups, respectively. The mechanical ventilation time, length of hospital stay, and length of stay in the intensive care unit were significantly shorter in the deep breathing group ($p<0.05$). In the deep breathing group, the mean SpO_2 values evaluated before surgery, on the first day in the Cardiovascular Surgery Unit, and on the day of discharge were significantly higher than the control group ($p<0.05$).

*Correspondence:
Hatice Öner Cengiz
htcnr8878@gmail.com
Full list of author information is available at the end of the article

Conclusion Deep breathing exercises with an incentive spirometer initiated in the preoperative period contribute to a reduction in postoperative pulmonary complication rates, shortening of mechanical ventilation time, length of stay in the intensive care unit, length of hospital stay, and improvement of pre- and postoperative oxygenation.

Trial registration The trial was registered on June 17, 2022, at https://www.clinicaltrials.gov/, registration number NCT05428722.

Keywords Breathing exercises, Cardiac surgery, Postoperative complications, Hospital stay, Nursing

Introduction

Coronary artery bypass grafting (CABG) is a surgical procedure that involves bypassing blocked coronary arteries with the objective of restoring blood flow to the heart [1]. Patients who have undergone cardiac surgery are at an elevated risk of developing postoperative pulmonary complications (PPCs) [1, 2]. Furthermore, approximately one-quarter of patients who have undergone cardiac surgery and do not have chronic pulmonary dysfunction develop a PPC. PPCs range from a mild respiratory infection to acute respiratory failure, which may necessitate the use of oxygen therapy and invasive or non-invasive mechanical ventilation (MV) support [3]. PPCs have been demonstrated to result in elevated healthcare expenditures [4], extended periods of hospitalisation, and an increased prevalence of morbidity and mortality [3]. The development of a PPC is influenced by a number of factors. Contributing factors have included surgical stress and anaesthesia, the systemic inflammatory response and oxidative stress from cardiopulmonary bypass, the type of surgery performed, inadequate pain management, the anaesthesia protocol employed, the use of blood products, and diaphragmatic dysfunction [2].

A significant contributing factor to the development of PPCs is preoperative respiratory muscle weakness [5]. A variety of respiratory physiotherapy techniques are employed with the objective of alleviating muscle weakness and preventing PPCs in patients who have undergone cardiac surgery. The main aims of respiratory physiotherapy are to improve ventilation-perfusion compliance, increase lung volumes, improve mucociliary clearance, and reduce pain [6]. The most commonly used methods are incentive spirometry (IS) and deep breathing exercises (DBE), which are easy to use, straightforward, and inexpensive [1]. IS is a method that provides visual feedback based on the patient's motivation and cooperation in deep breathing [1] to maintain alveolar patency after cardiac surgery [7], improve lung volumes by ensuring oxygen delivery and proper ventilation [1, 7], ensure maximum bronchial dilatation, and produce an effective cough [1]. In clinical practice, DBEs with IS is usually initiated in the post-operative period [8]. However, it has been reported that inadequate physical adaptation and respiratory muscle weakness in the preoperative period are closely associated with PPCs leading to a prolonged hospital stay and increased mortality [5]. There are limited studies investigating the efficacy of preoperative IS application only in patients undergoing open-heart surgery [9, 10]. In addition, the literature evaluating the effect of IS and DBEs on respiratory complications in patients undergoing open-heart surgery is inconsistent. Some studies have found a statistically significant lower incidence of atelectasis with IS and DBEs [10–12], while others have found no effect [9, 13, 14]. The aim of this study was to determine the effects of preoperative DBE and IS on respiratory parameters and complications in patients undergoing open-heart surgery. It is anticipated that the data obtained from this study will contribute to the existing literature on the effects of initiating IS and DBE in the preoperative period in patients undergoing open-heart surgery. Furthermore, it may shed light on preoperative nursing care practices to prevent PPCs.

Methods

Study design and participants

The randomized controlled study was conducted at the Cardiovascular Surgery Unit (CVSU) of a training and research hospital between June 2022 and January 2023. This study was registered in a clinical trial database (NCT05428722||(https://www.clinicaltrials.gov/) (June 17, 2022).

The G*Power (version 3.1.9.4) test was used to determine sample size. A priori analysis was based on the mean hypoxic events (intervention: 9.4 ± 7.6 vs. control 30.9 ± 26.2) in 89 patients underwent for elective cardiac surgery in the study by Alwekhyan et al. [8]. It was determined that a total of 62 patients (31 patients in each group) should be included when the Independent Sample t-test was two-tailed, with a predicted effect size of 1.11 and a (type 1 or 2) error level of 5% with a power of 99%. Considering that the dropout rate was 15% in the reference study, 72 patients (36 in each group) were included in this study. Three patients who died in the deep breathing group, one patient who did not comply with the exercises and two patients who died in the control group were excluded from the study. Thus, the study included 66 patients (32 in the deep breathing group; and

34 in the control group). The study flowchart according to the Consolidated Standards of Reporting Trials (2010) is shown in Fig. 1.

Inclusion criteria were (a) 18 years or older; (b) Turkish speaking and understanding; (c) conscious, oriented, and cooperative; (d) undergoing cardiac surgery for the first time; (e) undergoing CABG, valve surgery or combined open-heart surgery; (f) did not require oxygen support in the preoperative period; and (g) had a Medical Research Council Scale (MRCS) score of 1.

Patients were excluded if they (a) underwent emergency surgery, (b) had complete (100%) occlusion of the left and right main coronary arteries, (c) had a concomitant vascular aneurysm, (d) had a chronic respiratory disease (asthma, chronic obstructive pulmonary disease, bronchiectasis, etc.), (e) refused to participate in the study, (f) had heart failure, and (g) had incomplete data. Patients who (a) died during surgery and (b) did not comply with IS and exercises were considered patients lost to follow-up.

Randomization and blinding

In this study, 72 patients who met the inclusion criteria were assigned to groups using the block randomization method (36 patients in the deep breathing group and 36 patients in the control group). The assignment of patients to groups by block randomization method was performed through a computer program [15]. A coin was tossed to determine whether Groups A and B represented the deep breathing and control groups, respectively. Group A was the deep breathing group and Group B was the control group. It was not possible

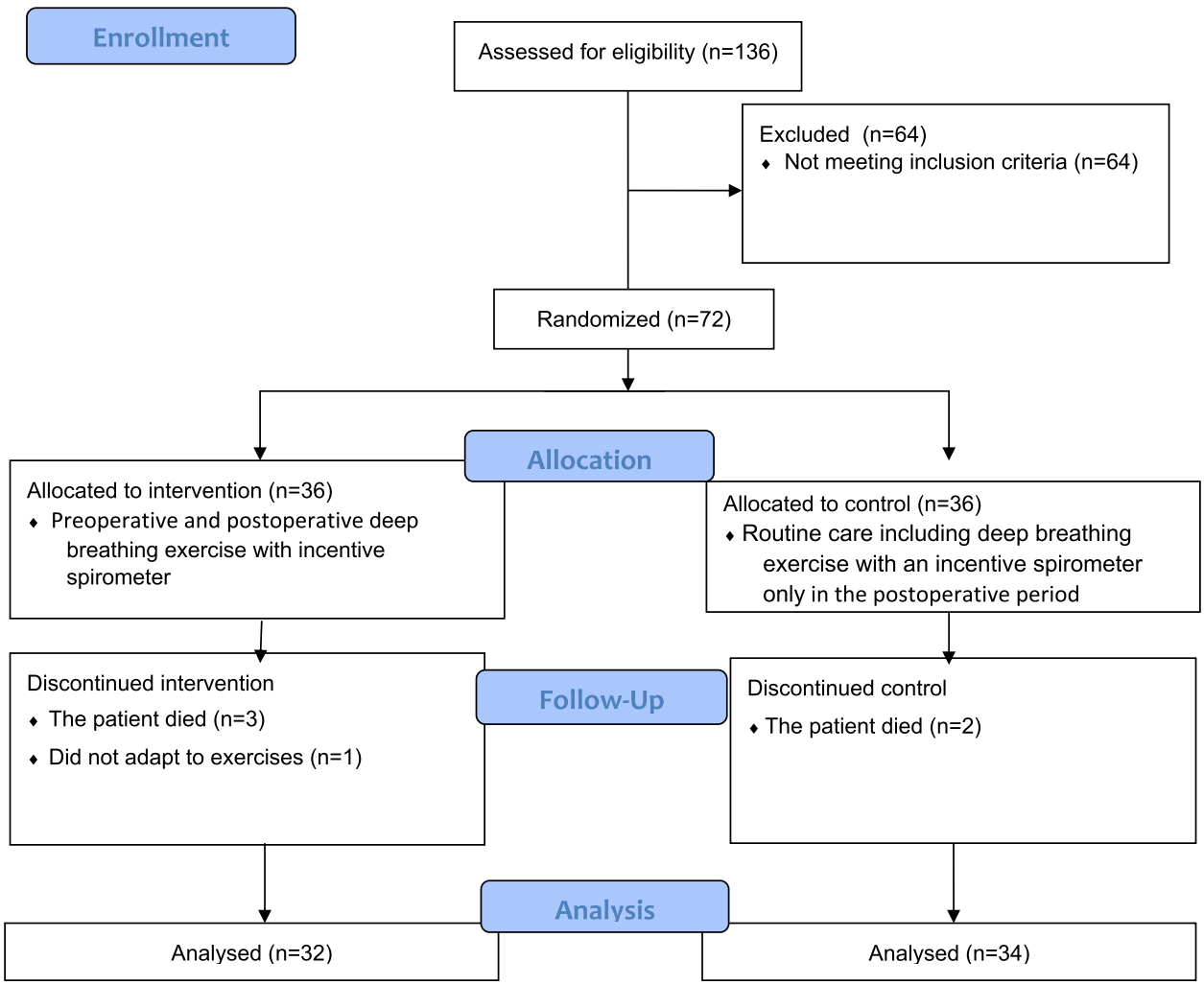

Fig. 1 The study flowchart according to CONSORT 2010

for the patients and the researcher to be blinded to the study.

Data collection tools

Medical Research Council Scale (MRCS)

The Medical Research Council Scale (MRCS) was used to determine the severity of dyspnea in the patients included in the study. It is a five-item scale ranging from 1 (no dyspnea) to 5 (very severe dyspnea) based on various physical activities that cause dyspnea [16]. In this study, the items on the scale were read to patients, who were then asked to choose the number that best described their dyspnoea. According to the scale, patients with a "1", or no dyspnoea, were included in the study.

Sociodemographic and medical data form

The Sociodemographic and Medical Data Form, which was prepared by the researchers, consists of a total of 13 items including sociodemographic and medical questions. Sociodemographic and medical data forms were administered to all patients on the first day of hospitalisation.

Patient follow-up form

Finally, the Patient Follow-up Form was a researcher-administered form used to monitor respiratory rate (RR), oxygen saturation (SpO_2), arterial blood gas parameters (pH, pO_2, pCO_2, SaO_2, HCO_3), and posteroanterior (PA) Chest X-ray during different phases of the patient's care.

Observation indicators

The measurement times of the observation indicators are given in Fig. 2.

Primary outcomes

Assessment of respiratory parameters (RR, SpO_2 level, arterial blood gas parameters, Chest X-ray), and PPCs development. *The RR* was counted four times daily by the research nurse. RR was measured by the research nurse for one minute after a rest period of at least 15 min. *SpO_2 levels* were determined four times a day, after a 15-min interval in patients receiving oxygen support, using a Braun YK-81CEU Pulse oximeter (China) (pulse and oxygen meter), and the mean value was recorded. SpO_2 was measured on room air. The pulse oximetry device was disinfected, and the same device was used for all patients. The calibration of the device was verified at the

The first day of hospitalization	Before surgery	The first day at CVSU	Discharge day
Sociodemographic and Medical Data Form			
Respiratory rate	Respiratory rate	Respiratory rate	Respiratory rate
SpO_2 level	SpO_2 level	SpO_2 level	SpO_2 level
	Arterial blood gas parameters (pH, PaO_2, $PaCO_2$, SaO_2, HCO_3)	Arterial blood gas parameters (pH, PaO_2, $PaCO_2$, SaO_2, HCO_3)	
PPC monitoring	PPC monitoring	PPC monitoring	PPC monitoring
PA Chest X-Ray	If necessary (complications developed and were deemed necessary)		PA Chest X-Ray

CVSU:Cardiovascular Surgery Unit

Fig. 2 Data collection process of the study

beginning of the study. To avoid measurement error (or bias), assessments were conducted by a single researcher. A pulse oximeter was placed over the nail bed. *Arterial blood gas analysis* was routinely performed at (First day of hospitalisation, before surgery, postoperative 1st day and discharge day) certain times in the CVSU clinic and studied on the same device in the laboratory. *PA Chest X-rays* of the patients were evaluated. All patients were evaluated by a medical doctor researcher on the first day of hospitalisation if complications developed and were deemed necessary, and the last PA chest X-ray was taken before discharge. *A PPC* was defined as the occurrence of at least one pulmonary complication among atelectasis, pleural effusion, respiratory failure, pneumonia, pneumothorax, bronchospasm, or aspiration pneumonia. The diagnosis of one of these conditions by a medical doctor was determined as the criterion. Classification of PPCs was made according to the Dindo-Clavien postoperative surgical complications classification. According to this classification, postoperative complications were classified as Grade I, II, IIIA, IIIB, IVA, IVB, and V [17].

Secondary outcomes

MV time, postoperative length of intensive care unit (ICU) stay, and duration of hospital stay were considered secondary outcomes in our analysis. MV duration was recorded in hours from the moment the patient was admitted to the postoperative intensive care unit until extubation. The day of admission to the ICU after surgery was considered the patient's first postoperative day. The time from this day until the day the patient was transferred to the CVSU was recorded as the postoperative intensive care unit stay. The number of days from the first hospitalisation to discharge was recorded as the length of hospital stay.

Implementation of the initiative

Each patient was included in the study on the day of admission to the CVSU. All patients were followed up until discharge.

Routine treatment and care

All patients included in the study received routine cardiovascular surgical care. In addition, all patients included in the study received routine treatment and care in the ICU. Postoperatively, in the ICU patients were first administered MV with a fraction of inspired oxygen (FiO2) of 45–50%, tidal volumes of 6–8 ml/kg and RR adjusted (according to arterial blood gases) in the Synchronized Intermittent Mandatory Ventilation and Continuous Positive Airway Pressure modes, respectively. A routine chest X-ray was performed after the patient was transferred to the ICU to examine the location of the endotracheal tube and the overall condition of the lungs. Close monitoring was performed daily for the development of PPCs. In the CVSU DBEs with IS were started after open-heart surgery for all patients.

Deep breathing group

In this study, in addition to routine treatment and care, patients in the deep breathing group received DBE training with IS on the first day of hospitalisation (preoperative period). IS training was given practically by the nurse at the bedside using an IS. The nurse first introduced the IS and explained how it is used. Then, the nurse demonstrated how to properly position and hold the IS during the exercise. Finally, the steps of inspiration, holding the breath in and expiration were demonstrated. The patient performed DBEs with IS in front of the study nurse. Areas where the patient made mistakes during the exercise were corrected. All questions asked by the patient were answered. The first training took approximately 30–45 min. The need for retraining was assessed. None of the patients required retraining. Subsequently, the patients performed DBE with the IS until the time of surgery. Thus, patients were made to do deep breathing exercises from the first day they were admitted to the CVSU. After the patient was extubated in the ICU postoperatively, DBE with IS was re-started in the ICU after their clinical condition stabilized and continued until discharge. DBEs with IS were performed as inspiration 5–10 times per hour, holding the breath in for 3–5 s and then expiration 5–10 times. Patients were instructed to start the morning after breakfast and to inspire 5–10 times per hour with IS, hold their breath for 3–5 s, and then expire 5–10 times per hour until they fell asleep in the CVSU. The research nurse instructed patients that they should exercise every hour, and the alarms of the patients' cell phones were set to ring every hour as reminders. The start and end times of the exercise were decided together with the patient; usually, the patient's waking and bedtimes were considered. No side effects of the intervention were observed in patients in the deep breathing group.

Control group

Patients in the control group received hospital routine physiotherapy. No additional intervention was applied. Patients in this group began DBE with IS after surgery as part of their routine care in the CVSU.

Statistical analysis

Data analysis was performed using the Statistical Package for Social Sciences 25 (IBM SPSS Statistics Version 25, USA). A normality test was performed to determine the tests used in the data analysis. The mean and

standard deviation values were used for age, body mass index (BMI), and duration of smoking, and number and percentage values were used for all other variables. An independent sample t-test was used for intergroup comparisons of age, BMI, smoking duration, duration of surgery (hours), MV time (hours), length of hospital stay (days), postoperative length of ICU stay (days), aortic cross-clamp (AXC) duration (min), cardiopulmonary bypass pump (CBP) duration (min), arterial blood gas parameters, RR and SpO_2 levels. A paired sample t-test was used for intragroup comparisons of RR, O_2, CO_2, and SpO_2 levels. A chi-square test was used to determine the relationship between the presence of a PPC, the presence of complications other than a PPC, and postoperative PA chest X-ray features. A Pearson correlation test was used to determine the relationship between MV time (hours), duration of surgery (hours), postoperative length of ICU stay (days), CBP duration (min), and length of hospital stay (days). Pearson correlation tests were also used to determine the relationship between MV time (hours), duration of surgery (hours), CBP duration (min), AXC duration (min), and postoperative length of ICU stay (days).

Results

Seventy-two patients were enrolled, 66 patients completed the study. Two patients in the deep breathing group died of bleeding and cardiac tamponade, while one patient in this group died of arrhythmia; one patient from the control group died of arrhythmia and one patient from the control group died of bleeding. In this study, patients in the deep breathing and control groups were similar in terms of mean age, mean BMI, sex, marital status, education, history of smoking, duration of smoking, surgical intervention, presence of chronic disease, presence of complications other than PPC, and chronic disease characteristics (Table 1).

It was determined that 3.1% ($n=1$) of the patients in the deep breathing group developed pneumonia and had a pathologic postoperative chest X-ray. In the control group, 23.5% ($n=8$) of the patients developed a PPC, of which 8.8% had atelectasis and had a pathological postoperative chest X-ray. PPCs occurring in the deep breathing and control groups were classified as Grade I and Grade II according to the Dindo-Clavien classification [13]. When comparing the deep breathing and control groups, there was a statistically significant difference in terms of the development of PPCs ($p<0.05$). There was a statistically significant higher number of patients in the control group with a pathological postoperative PA chest X-ray ($p<0.05$) (Table 1).

A comparison of the surgical intervention-related characteristics and arterial blood gas parameters of the patients is presented in Table 2. There was no significant difference between the mean duration of surgery, AXC duration, and CBP duration ($p>0.05$) between groups. MV time (16.58 ± 8.94), duration of hospital stay (18.97 ± 6.26), and postoperative length of ICU stay (4.47 ± 1.87) of patients in the deep breathing group were significantly shorter than those in the control group (11.59 ± 5.04; 16.03 ± 4.99; 3.51 ± 1.54, respectively) ($p<0.05$). When examining blood gases; the mean pCO_2 on the first day in the CVSU (33.63 ± 3.31), and on the day of discharge (32.73 ± 4.87) of patients in the deep breathing group were significantly lower than those in the control group (36.43 ± 4.71; 35.34 ± 4.01, respectively) ($p<0.05$). The difference between the mean values of all other parameters and at different timepoints were not significant ($p>0.05$).

A comparison of mean RR and SpO_2 levels between groups is presented in Table 3. The mean SpO_2 values of the patients in the deep breathing group before surgery (97.59 ± 0.91), on the first day in the CVSU (93.15 ± 3.71), and on the day of discharge (96.37 ± 1.87) were significantly higher than the control group ($p<0.05$). Moreover, it was found that the mean RR of the patients in the deep breathing group on the first day in the CVSU (20.43 ± 2.36) was significantly lower than in the control group ($p<0.05$).

A comparison of respiratory rate, O_2, CO_2, and SpO_2 levels intra-group at patient follow-up is presented in Table 4. In the deep breathing group, the mean SpO_2 (97.59 ± 0.91) and PaO_2 (88.07 ± 8.44) levels before surgery were significantly higher than those on the first day of hospitalisation (96.84 ± 1.24, 84.83 ± 10.42, respectively) ($p<0.05$). The SpO_2 levels on the day of discharge were significantly higher than those on the first day in the CVSU. The RR levels on the day of discharge were statistically significantly lower than those on the first day in the CVSU in both the intervention and the control groups ($p<0.05$).

The correlation between some characteristics of the patients and the length of hospital stay and postoperative length of ICU stay is presented in Table 5. Accordingly, it was determined that there was a weak positive correlation between the postoperative length of ICU stay and MV time (r:0.23; $p<0.05$) as well as AXC duration (r:0.29; $p<0.05$). Also, there was a weak positive relationship between the postoperative length of ICU stay and MV time (r:0.23; $p<0.05$) and AXC duration (r:0.29; $p<0.05$).

Discussion

Cardiopulmonary bypass is responsible for a systemic inflammatory response that causes pulmonary ischemia–reperfusion injury [2]. Additionally, factors such as patient respiratory function, type of surgery, type of pain

Table 1 Baseline socio-demographic and medical characteristics of the deep breathing and control groups

	Deep Breathing Group ($n=32$)	Control Group ($n=34$)	Test	*p*
Characteristics	**Mean ± SD**	**Mean ± SD**		
Age (years)	60.25 ± 13.08	60.85 ± 12.51	−0.19[a]	0.84
Body mass index(kg/m^2)	27.42 ± 6.51	26.81 ± 4.84	0.42[a]	0.66
Smoking duration (Mean ± SD)	31.47 ± 17.24	28.10 ± 20.69	0.55[a]	0.58
	n(%)	**n(%)**		
Gender				
Female	9(28.1)	12(35.3)	0.39[b]	0.53
Male	23(71.9)	22(64.7)		
Marital status				
Married	30(93.8)	32(94.1)	0.00[b]	0.95
Single	2(6.3)	2(5.9)		
Education				
Illiterate	2(6.2)	5(14.7)	6.05[b]	0.30
Primary education	18(56.2)	21(61.8)		
High school	6(18.8)	6(17.6)		
University and above	6(18.8)	2(5.9)		
History of smoking				
Yes	15(46.9)	13(38.2)	0.50[b]	0.47
No	17(53.1)	21(61.8)		
Surgical intervention				
Coronary Artery Bypass Graft	24(75.0)	26(79.4)		
Mitral Valve Replacement	3(9.4)	2(5.9)		
Aortic Valve Replacement	3(9.4)	3(7.7)		
Tricuspid Valve Replacement	1(3.1)	2(5.9)		
Aortic Valve Replacement and Mitral Valve Replacement	1(3.1)	1(1.1)		
Presence chronic disease				
Yes	19(59.4)	26(76.5)	2.22[b]	0.13
No	13(40.6)	8(23.5)		
Chronic disease[c]				
Coronary Artery Disease	24(75.0)	26(79.4)		
Heart Valve Disease	8(25.0)	8(20.6)		
Diabetes Mellitus	13(40.6)	15(44.1)		
Cardiac diseases	0(0.0)	2(5.9)		
Hypertension	10(31.3)	13(38.2)		
Liver disease	0(0.0)	1(2.9)		
Cancer	0(0.0)	1(2.9)		
Chronic Renal Diseases	0(0.0)	3(8.8)		
Hipo- or hyper-thyroidism	0(0.0)	2(5.9)		
Benign Prostatic Hyperplasia	1(3.1)	1(2.9)		
Presence of PPC				
Yes	1(3.1)	8(23.5)	5.82	0.01
No	31(96.9)	26(76.5)		
PPC				
Atelectasis	0(0.0)	3(8.8)		
Pneumonia	1(3.1)	2(5.9)		
Pleural effusion	0(0.0)	2(5.9)		
Emphysema	0(0.0)	1(2.9)		
Presence of complications other than PPC				
Yes	16(50.0)	17(50.0)	2.95	0.08

Table 1 (continued)

No	16(50.0)	17(50.0)		
Complications other than PPC[e]				
Urinary tract infection	0(0.0)	3(8.8)		
Atrial fibrillation	4(12.5)	9(25.5)		
Acute Renal Injury	10(31.3)	3(8.8)		
Cardiac arrest	1(3.1)	1(2.9)		
Acute Respiratory Distress Syndrome	1(3.1)	2(5.9)		
Reintubation	2(6.3)	0(0.0)		
Sternal wound infection	1(3.1)	1(2.9)		
Hemodynamic instability	0(0.0)	2(5.9)		
Catheter-related infection	1(3.1)	1(2.9)		
Sepsis	1(3.1)	0(0.0)		
Preoperative Chest X-ray				
Normal	32(100.0)	34(100.0)		
Postoperative Chest X-ray				
Normal	31(96.9)	26(76.5)	5.82	0.01
Pathological	1(3.1)	8(23.5)		
Chest X-ray before discharge				
Normal	32(100)	34(100)		

PPC Postoperative pulmonary complication

[a] Independent sample t-test

[b] Chi square test

[c] More than one option is ticked

[d] Chi square test

[e] More than one option is ticked

management, anaesthesia protocol, and use of blood products are associated with the development of PPCs [2]. Atelectasis is a well known complication of general anesthesia which may persist for several days for a variety of reasons [18]. In this sense, DBEs have been shown to improve postoperative lung expansion and ventilation [8] and reduce the occurrence and severity of PPCs [10]. Incentive spirometry is used in lung expansion therapy to maintain alveolar patency and improve pulmonary volumes in postoperative cardiac surgical patients [7]. A meta-analysis showed that the use of IS alone had little or no effect on reducing pulmonary complications after cardiac, thoracic, and lower abdominal surgery [19]. Similarly, in other studies, it was determined that respiratory exercise initiated with IS in the preoperative period had no effect on atelectasis and hypoxemia after CABG [9], and it was determined that there was no significant difference in PPCs between the patients in the IS group and the patients in the DBE and control group [20]. In a study conducted with patients who underwent lung resection, it was determined that compliance with postoperative IS use was better and the incidence of PPCs was significantly lower in the group that received preoperative DBE with IS [21]. In our study, preoperative DBE combined with IS had a statistically significant lower incidence of atelectasis in patients after open-heart surgery. This is similar to the findings of a meta-analysis which examined the effect of preoperative exercise training on PPCs in patients who underwent a major surgical intervention (cardiac, lung, esophageal, or abdominal surgery). Preoperative exercise training resulted in significantly reduced development of PPCs in the postoperative period [5]. Additionally, our results are in agreement with a previous study in CABG patients in which DBE with IS in the preoperative period significantly reduced the incidence of postoperative atelectasis [10]. In this study, it was found that the number of PPCs in the deep breathing group was lower than that in the control group. Moreover, no atelectasis was seen in the patients in the deep breathing group, only one patient in the deep breathing group developed pneumonia, whereas most of the patients with PPCs in the control group developed atelectasis. The results of this study lend support to the findings of other studies that have reported that preoperative DBE with IS has a statistically significant lower incidence of atelectasis in patients undergoing open-heart surgery [10–12]. Deconditioning and respiratory muscle weakness in the preoperative period are closely associated with PPCs, which lead to a prolonged hospital stay and increased mortality [5]. Our findings are consistent with

Table 2 Comparison of the surgical intervention-related characteristics and arterial blood gas parameters between groups

Characteristics Associated with Surgical Intervention	Deep Breathing Group ($n=32$)	Control Group ($n=34$)	Test[a]	p
	Mean ± SD	Mean ± SD		
Duration of surgery (hours)	5.53 ± 0.90	5.48 ± 0.78	0.19	0.84
Mechanical ventilation time (hours)	11.59 ± 5.04	16.58 ± 8.94	−2.76	0.00
Length of hospital stay (days)	16.03 ± 4.99	18.97 ± 6.26	−2.09	0.04
Postoperative length of ICU stay (days)	3.51 ± 1.54	4.47 ± 1.87	−2.24	0.02
Length of preoperative hospital stay (days)	3.62 ± 2.01	3.85 ± 2.87	−0.37	0.71
AXC duration (min)	47.25 ± 21.88	47.79 ± 13.68	−0.12	0.90
CBP duration (min)	86.93 ± 27.16	90.76 ± 22.44	−0.62	0.53
Arterial Blood Gas Parameters				
First day of hospitalization				
pH	7.40 ± 0.04	7.38 ± 0.06	1.56	0.12
pO_2	84.83 ± 10.42	89.76 ± 11.99	−1.77	0.08
pCO_2	35.67 ± 4.50	38.02 ± 9.15	−1.31	0.19
SaO_2	95.72 ± 1.93	96.44 ± 2.27	−1.38	0.17
HCO_3	23.43 ± 2.02	23.14 ± 1.83	0.60	0.54
Before surgery				
pH	7.39 ± 0.49	7.39 ± 0.05	−0.65	0.51
pO_2	88.07 ± 8.44	90.85 ± 12.79	−1.03	0.30
pCO_2	36.81 ± 4.91	38.08 ± 9.21	−0.73	0.46
SaO_2	96.18 ± 1.75	96.81 ± 2.24	−1.25	0.21
HCO_3	22.66 ± 2.03	23.35 ± 2.55	−1.21	0.22
The first day at CVSU				
pH	7.41 ± 0.05	7.40 ± 0.06	0.15	0.87
pO_2	98.02 ± 16.60	96.68 ± 23.62	0.26	0.79
pCO_2	33.63 ± 3.31	36.43 ± 4.71	−2.77	0.00
SaO_2	97.37 ± 1.55	97.10 ± 1.70	0.61	0.51
HCO_3	21.64 ± 2.56	28.18 ± 32.43	−1.13	0.26
Discharge day				
pH	7.43 ± 0.07	7.30 ± 0.51	1.31	0.19
pO_2	94.32 ± 8.05	92.96 ± 5.22	0.81	0.41
pCO_2	32.73 ± 4.87	35.34 ± 4.01	−2.37	0.02
SaO_2	96.44 ± 2.94	96.72 ± 2.00	−0.46	0.64
HCO_3	22.02 ± 4.58	21.56 ± 2.03	0.53	0.59

ICU Intensive Care Unit, *AXC* aortic clamp, *CBP* cardiopulmonary bypass pump, *CVSU* Cardiovascular Surgery Unit

[a] Independent sample t-test

those of previous studies that have shown that preoperative DBEs with IS have positive effects on respiratory function in patients undergoing open-heart surgery and subsequently reduces the development of PPCs.

Mechanical ventilation plays an important role in pulmonary injury and is considered to be an independent risk factor for the development of PPCs after cardiac surgery [22]. MV duration was significantly shorter in patients in the deep breathing group than in the control group. This is consistent with other studies in CABG patients that have shown that the duration of MV was significantly shorter in patients who started DBE with IS preoperatively [10, 19]. Yet another study of preoperative DBE and IS in CABG patients reported that there was no difference in MV duration [9]. It is likely that the difference between the results of these studies may be due to differences in care protocols in the different countries and institutions in which these previous trials have been performed. The results of this study suggest that DBE with IS initiated in the preoperative period in patients undergoing open-heart surgery contributes to a shorter-term termination of MV support in the postoperative period.

Table 3 Comparison of mean respiratory rate and SpO2 levels between groups at patient follow-up

Time/ Characteristics	Deep Breathing Group ($n=32$)	Control Group ($n=34$)	Test[a]	*p*
	Mean ± SD	Mean ± SD		
First day of hospitalization				
Respiratory rate	20.37 ± 1.49	20.20 ± 0.91	0.55	0.57
SpO_2	96.84 ± 1.24	96.97 ± 0.93	−0.46	0.64
Before surgery				
Respiratory rate	20.06 ± 1.31	20.00 ± 1.75	0.16	0.87
SpO_2	97.59 ± 0.91	97.20 ± 0.68	1.96	0.05
The first day at CVSU				
Respiratory rate	20.43 ± 2.36	21.82 ± 2.49	−2.31	0.02
SpO_2	93.15 ± 3.71	90.70 ± 5.08	2.22	0.03
Discharge day[b]				
Respiratory rate	18.96 ± 1.85	19.85 ± 1.07	−2.38	0.20
SpO_2	96.37 ± 1.87	95.02 ± 2.79	2.28	0.02

I Intervention group, *C* Control group, *Postop* Postoperative, *CVSU* Cardiovascular Surgery Unit

[a] Independent sample t-test

[b] Discharge day measurements of all patients were taken as the last measurement

It is important that patients stay in the hospital for a short time to avoid additional complications and increased healthcare costs. In our study, the duration of hospitalisation was found to be significantly shorter in the deep breathing group. A study of CABG patients showed that the length of hospital stay was significantly shorter in patients who underwent DBE with IS prior to surgery [10]. A meta-analysis of the effects of preoperative exercise training in patients undergoing major surgery (heart, lung, oesophageal or abdominal surgery) found that the length of hospital stay was significantly reduced [5]. In a study of patients undergoing CABG, the postoperative hospital stay was shorter in the group that received preoperative inspiratory muscle training compared with the control group [23]. One study found that there was no significant difference in the length of hospital stay between patients in a DBE with IS group versus a DBE alone control group [20]. These results can be interpreted as meaning that starting DBE with IS in the preoperative period may shorten the recovery time of patients after CABG and help them to return to their normal life in a shorter time.

One study found that the length of ICU stay of patients who underwent breathing exercises with nurse-guided IS in the postoperative period was significantly shorter than patients with self-administered IS [8]. In this study, the length of postoperative ICU stay was significantly shorter in the DBE and IS group as compared to the control group. In our data, there was a weak positive relationship between the length of postoperative ICU stay and the length of hospitalisation as well as a weak positive relationship between the length of postoperative ICU stay and AXC duration. AXC duration is an important metric in cardiac surgery. A complication associated with AXC duration is myocardial ischemia. Although hypothermia and cardioplegia solutions are used to prevent this complication, it still remains an important problem [24]. The increased myocardial ischemia from increased AXC durations may lead to increased need for longer ICU stays postoperatively. There are many factors that lead to prolongation of a ICU stay. The results of this study show that the duration of stay in the ICU is shorter in patients in whom DBE with IS was started in the preoperative period. The presumed benefits of DBE and IS of increased respiratory muscle strength and lung capacity in the preoperative period can affect all other systems by increasing oxygenation. This increased oxygenation can lead to reduced length of stays in the ICU and may contribute to shortening the overall hospital stay and recovery period.

Decreased oxyhemoglobin saturation level is a common pulmonary complication after CABG surgery [8]. Hypoxia causes deterioration in tissue perfusion. Decreased tissue perfusion leads to tissue hypoxia by disruption of cellular metabolism. Tissue hypoxia leads to decreased perfusion of vital organs and cell death. All body systems are significantly affected by impaired tissue oxygenation [25]. In our study, it was found that the mean pCO_2 levels of the patients in the deep breathing group on the first day in the CVSU and on the day of discharge were significantly lower than those in the control group. Moreover, it was found that the mean SpO_2 values of the patients in the deep breathing group evaluated before surgery, on the first day in the CVSU, as well as on the day of discharge were significantly higher than those in the control group. In a study conducted in patients undergoing CABG, it was found that the duration of dependence on oxygen therapy was shorter in the group receiving preoperative inspiratory muscle training compared to the control group [23]. In another study, it was determined that the incidence of hypoxic events was significantly less in patients who underwent breathing exercises with nurse-guided IS in the postoperative period [8]. In a study conducted with patients who underwent CABG, it was shown that the median of the amount arterial blood oxygen and SpO_2 of patients who underwent DBE with IS before surgery significantly improved than the control group [10]. In another study, it was determined that SpO_2 was higher and RR was lower in patients who performed DBE with IS compared to patients who performed deep breathing alone [1]. The findings of this

Table 4 Comparison of respiratory rate, O_2, CO_2, and SpO_2 levels intra-group at patient follow-up

Time-Characteristics	Deep Breathing Group ($n=32$) Mean ± SD	Control Group ($n=34$) Mean ± SD
First day of hospitalization-SpO_2	96.84 ± 1.24	96.97 ± 0.93
Before surgery-SpO_2	97.59 ± 0.91	97.20 ± 0.68
Test*/p	−3.27/0.03	−1.34/0.18
First day of hospitalization- PaO_2 (arterial blood gas)	84.83 ± 10.42	89.76 ± 11.99
Before surgery-PaO_2 (arterial blood gas)	88.07 ± 8.44	90.85 ± 12.79
Test*/p	−2.46/0.02	−1.60/0.11
First day of hospitalization-CO_2 (arterial blood gas)	35.71 ± 4.57	38.02 ± 9.15
Before surgery-CO_2 (arterial blood gas)	36.81 ± 4.97	38.08 ± 9.21
Test*/p	−1.69/0.10	−0.12/0.90
First day of hospitalization-Respiratory rate	20.37 ± 1.49	20.20 ± 0.91
Before surgery-Respiratory rate	20.06 ± 1.31	20.00 ± 1.75
Test*/p	1.28/0.20	0.71/0.48
Postop 1st day-SpO_2	93.15 ± 3.71	90.70 ± 5.08
Discharge day-SpO_2	96.37 ± 1.87	95.02 ± 2.79
Test*/p	−5.33/0.00	−4.59/0.00
The first day at CVSU- PaO_2 (arterial blood gas)	98.02 ± 16.60	96.68 ± 23.62
Discharge day- PaO_2 (arterial blood gas)	94.32 ± 8.05	92.96 ± 5.22
Test*/p	1.33/0.19	0.94/0.35
The first day at CVSU-CO_2 (arterial blood gas)	33.63 ± 3.31	36.43 ± 4.71
Discharge day-CO_2 (arterial blood gas)	32.73 ± 4.87	35.34 ± 4.01
Test*/p	1.09/0.28	1.37 ± 0.17
The first day at CVSU-Respiratory rate	20.43 ± 2.36	21.82 ± 2.49
Discharge day-Respiratory rate	19.12 ± 1.80	19.85 ± 1.07
Test*/p	2.45/0.02	5.10/0.00

Postop Postoperative, *CVSU* Cardiovascular Surgery Unit

* Paired sample t-test

Table 5 The relationship between some characteristics all of the patients and the length of hospital stay and postoperative length of ICU stay

	Length of hospital stay (days)
Characteristics	r/p
Mechanical ventilation time (hours)	0.19/0.11
Duration of surgery (hours)	0.07/0.57
Postoperative length of ICU stay (days)	0.32/0.00
CBP duration (min)	0.09/0.46
	Postoperative length of ICU stay (days)
Characteristics	r/p
Mechanical ventilation time (hours)	0.23/0.05
Duration of surgery (hours)	0.10/0.39
CBP duration (min)	0.17/0.16
AXC duration (min)	0.29/0.01

ICU Intensive Care Unit, *AXC* aortic clamp, *CBP* cardiopulmonary bypass pump, *r* Pearson correlation

study are concurrent with the current literature, suggesting that starting DBEs with IS in the preoperative period can provide an increase in oxygenation and a decrease in carbon dioxide levels following surgery.

Strengths and limitations of the study

This study has several limitations. First, at the time of the study, the COVID-19 pandemic rules were strictly applied, especially for this high-risk group of patients. Pulmonary function tests were not routinely performed at our institution due to COVID-19 restrictions. Additionally, the device that allows bedside pulmonary function testing could not be purchased due to its high cost. Given this set of circumstances, preoperative pulmonary function testing could not be performed and respiratory parameters had to be assessed using RR, arterial blood gas parameters, PA chest X-ray, and SpO_2 values.

Second, participants were not blinded in this trial. However, the researcher who performed the randomisation, processed the data, and performed the statistical analysis was blinded. This design is inferior to a

double-blind randomised controlled trial because it makes it difficult to control for the placebo effect.

Thirdly, since many mechanisms are involved in achieving these functional and clinical improvements, further studies are needed to investigate the timing of IS intervention and its effect on maximum inspiratory/expiratory pressure.

This study could not evaluate the effects of other complications such as acute renal failure, atrial fibrillation, and reintubation on the development of PPCs. It would be useful in future studies to investigate these effects in a sufficient sample.

Despite these limitations, this study provides evidence that DBEs with IS would be beneficial if started preoperatively in patients undergoing open-heart surgery as opposed to the current standard of care of being initiated in the postoperative period in Turkey.

Conclusions

The use of deep breathing exercises with IS represents a cost-effective, accessible, and easily applied method for improving postoperative respiratory parameters. In patients who are planned to undergo open heart surgery, the initiation of DBEs with IS in the preoperative period may contribute to a reduction in the incidence of PPCs, the duration of MV, the length of stay in the ICU, the duration of hospitalisation, and an improvement in pre- and postoperative oxygenation.

Implication for nursing

In patients undergoing open heart surgery, it is crucial to commence DBEs with an IS under the guidance of a nurse in the preoperative period. This approach can enhance respiratory parameters, minimise or avert PPCs, and abbreviate the length of hospitalisation.

Abbreviations

PA	Posteroanterior
CVSU	Cardiovascular Surgery Unit
SpO_2	Oxygen saturation
MRCS	Medical Research Council Scale
CABG	Coronary artery bypass grafting
PPCs	Postoperative pulmonary complications
DBE	Deep breathing exercise
IS	Incentive spirometry
RR	Respiratory rate
ICU	Intensive care unit
MV	Mechanical ventilation
FiO_2	Fractional inspired oxygen
SPSS	Statistical Package for Social Sciences
BMI	Body mass index

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12871-025-02902-9.

Supplementary Material 1

Authors' contributions

Author Contribution HOC: Conceptualisation, Supervision, Methodology, Writing – original draft, Writing—review & editing ZUÖ: Data curation, Methodology, Writing—review & editing EG: Data curation, Writing—review & editing
All authors have been read and approved the final manuscript for submission.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Data availability

The datasets used and analyzed in the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This study was was performed following the guidelines of Declaration of Helsinki (2013). Ethical clearance was obtained from the The University of Health Sciences Ankara Education and Research Hospital Clinical Research Ethics Committee (Date: May 11, 2022; Approval number: 948/2022). Institutional permission was also obtained for the research. Informed written consent was obtained from the study participants, and privacy was ensured throughout data collection. Whether the patients participated in the study or not did not affect the treatment and care they received.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Author details

[1]Ankara University Faculty of Nursing, Department of Nursing, Department of Surgical Diseases Nursing, Ankara, Turkey. [2]Ankara Training and Research Hospital, Cardiovascular Surgery Clinic, Ankara, Turkey.

Received: 11 November 2024 Accepted: 13 January 2025
Published online: 24 January 2025

References

1. Zerang F, Amouzeshi A, Barkhordari-Sharifabad M. Comparison of the effect of incentive spirometry and deep breathing exercises on hemodynamic parameters of patients undergoing coronary artery bypass graft surgery: a clinical trial. J Vasc Nurs. 2022;40(3):134–9. https://doi.org/10.1016/j.jvn.2022.08.002.
2. Fischer MO, Brotons F, Briant AR, Suehiro K, Gozdzik W, Sponholz C, et al. Postoperative pulmonary complications after cardiac surgery: the VENICE International cohort study. J Cardiothorac Vasc Anesth. 2022;36(8 Pt A):2344–51. https://doi.org/10.1053/j.jvca.2021.12.024.
3. Ball L, Volta CA, Saglietti F, Spadaro S, Di Lullo A, De Simone G, Guarnieri M, Della Corte F, Serpa Neto A, Gama de Abreu M, Schultz MJ, Zangrillo A, Pelosi P, Bignami E. Associations between expiratory flow limitation and postoperative pulmonary complications in patients undergoing cardiac surgery. J Cardiothorac Vasc Anesth. 2022; 6(3):815–24. https://doi.org/10.1053/j.jvca.2021.07.035.
4. Sameed M, Choi H, Auron M, Mireles-Cabodevila E. Preoperative pulmonary risk assessment. Respir Care. 2021;66(7):1150–66. https://doi.org/10.4187/respcare.09154.
5. Assouline B, Cools E, Schorer R, Kayser B, Elia N, Licker M. Preoperative exercise training to prevent postoperative pulmonary complications in adults undergoing major surgery. A systematic review and meta-analysis with trial sequential analysis. Ann Am Thorac Soc. 2021;18(4):678–88. https://doi.org/10.1513/AnnalsATS.202002-183OC.
6. Lahoud R, Dauerman HL. Fall and rise of coronary intervention. J Am Heart Assoc. 2020;9(11):e016853. https://doi.org/10.1161/JAHA.120.016853.

7. Narayanan LT, Hamid SRGS. Incentive spirometry inspiratory capacity changes and predictors after open heart surgery: a 5-day prospective study. Med J Malaysia. 2020;75(3):226–34.
8. Alwekhyan SA, Alshraideh JA, Yousef KM, Hayajneh F. Nurse-guided incentive spirometry use and postoperative pulmonary complications among cardiac surgery patients: a randomized controlled trial. Int J Nurs Pract. 2022;28(2):e13023. https://doi.org/10.1111/ijn.13023.
9. Moradian ST, Heydari AA, Mahmoudi H. What is the role of preoperative breathing exercises in reducing postoperative atelectasis after CABG? Rev Recent Clin Trials. 2019;14(4):275–9. https://doi.org/10.2174/1574887114666190710165951.
10. Sweity EM, Alkaissi AA, Othman W, Salahat A. Preoperative incentive spirometry for preventing postoperative pulmonary complications in patients undergoing coronary artery bypass graft surgery: a prospective, randomized controlled trial. J Cardiothorac Surg. 2021;16(1):241. https://doi.org/10.1186/s13019-021-01628-2.
11. Oshvandi K, Bostanbakhsh A, Salavati M, Bakhsai M, Moghimbeighi A, Maghsoudi Z. Effect of respiratory exercises on the prevalence of atelectasis in patients undergoing coronary artery bypass surgery. Avicenna J Nurs Midwifery Care. 2020;27(6):432–40.
12. Nardi P, Pellegrino A, Pisano C, et al. The effect of preoperative respiratory physiotherapy and motor exercise in patients undergoing elective cardiac surgery: short-term results. Kardiochir Torakochirurgia Pol. 2019;16(2):81–7. https://doi.org/10.5114/kitp.2019.86360.
13. Freitas ER, Soares BG, Cardoso JR, Atallah ÁN. Incentive spirometry for preventing pulmonary complications after coronary artery bypass graft. Cochrane Database Syst Rev. 2012;2012(9):CD004466. https://doi.org/10.1002/14651858.CD004466.pub3. (Published 2012 Sep 12).
14. Overend TJ, Anderson CM, Lucy SD, Bhatia C, Jonsson BI, Timmermans C. The effect of incentive spirometry on postoperative pulmonary complications: a systematic review. Chest. 2001;120(3):971–8.
15. Sealed Envelope Ltd. Create a blocked randomisation list. 2021: [Online] Available from: https://www.sealedenvelope.com/simple-randomiser/v1/lists. Accessed 16 Mar 2022.
16. Bestall JC, Paul EA, Garrod R, Garnham R, Jones PW, Wedzicha JA. Usefulness of the Medical Research Council (MRC) dyspnoea scale as a measure of disability in patients with chronic obstructive pulmonary disease. Thorax. 1999;54(7):581–6. https://doi.org/10.1136/thx.54.7.581.
17. Dindo D, Demartines N, Clavien PA. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. Ann Surg. 2004;240(2):205–13. https://doi.org/10.1097/01.sla.0000133083.54934.ae.
18. Kotta PA, Ali JM. Incentive spirometry for prevention of postoperative pulmonary complications after thoracic surgery. Respir Care. 2021;66(2):327–33. https://doi.org/10.4187/respcare.07972.
19. Sullivan KA, Churchill IF, Hylton DA, Hanna WC. Use of incentive spirometry in adults following cardiac, thoracic, and upper abdominal surgery to prevent post-operative pulmonary complications: a systematic review and meta-analysis. Respiration. 2021;100(11):1114–27. https://doi.org/10.1159/000517012.
20. Manapunsopee S, Thanakiatpinyo T, Wongkornrat W, Chuaychoo B, Thirapatarapong W. Effectiveness of incentive spirometry on inspiratory muscle strength after coronary artery bypass graft surgery. Heart Lung Circ. 2020;29(8):1180–6. https://doi.org/10.1016/j.hlc.2019.09.009.
21. Bilyy A, El-Nakhal T, Kadlec J, Bartosik W, Tornout FV, Kouritas V. Preoperative training education with incentive spirometry may reduce postoperative pulmonary complications. Asian Cardiovasc Thorac Ann. 2020;28(9):592–7. https://doi.org/10.1177/0218492320957158.
22. Mathis MR, Duggal NM, Likosky DS, Haft JW, Douville NJ, Vaughn MT, Maile MD, Blank RS, Colquhoun DA, Strobel RJ, Janda AM, Zhang M, Kheterpal S, Engoren MC. Intraoperative mechanical ventilation and postoperative pulmonary complications after cardiac surgery. Anesthesiology. 2019;131(5):1046–62. https://doi.org/10.1097/ALN.0000000000002909. Erratum.In:Anesthesiology.2020Jan;132(1):217.doi:https://doi.org/10.1097/ALN.0000000000003038
23. Sahar W, Ajaz N, Haider Z, Jalal A. Effectiveness of pre-operative respiratory muscle training versus conventional treatment for ımproving post operative pulmonary health after coronary artery bypass grafting. Pak J Med Sci. 2020;36(6):1216–9. https://doi.org/10.12669/pjms.36.6.2899.
24. Yılmaz AR. The comparison of urea and creatinine levels of groups that ss 60 mins above and below of aortic clamp duration on coronary bypass patients. Istanbul Medipol University Health Sciences Institute Master's Thesis, Istanbul, 2019). (Original work published in Turkish)
25. Martin BM. Nursing Care of Patients in Shock. In: Williams LS, Hopper PD, eds. Understanding Medical Surgical Nursing. 5th Edition, F.A. Davis Company, Philadelphia, USA; 2015. p.133.

Publisher's Note