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Pre and postoperative nurse-guided incentive spirometry versus physiotherapist-guided pre and postoperative breathing exercises in patients undergoing cardiac surgery

An evaluation of postoperative complications and length of hospital stay

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Abstract

Atelectasis is the most occurring postoperative complication after cardiac surgeries. Postoperative respiratory exercises and incentive spirometry led to decrease in postoperative complications, especially atelectasis and hospital stay. The objectives of the study were to evaluate postoperative complications and length of hospital stay of patients who received pre and postoperative nurse-guided incentive spirometry against those of patients who received pre and postoperative breathing exercises by the physiotherapist in patients who underwent cardiac surgery. Data of patients who received 2 days preoperative and 2 days postoperative nurse-guided incentive spirometry with a spirometer (PPN cohort, n = 102) or received 2 days preoperative and 2 days postoperative breathing exercises by physiotherapist without spirometer (PPP cohort, n = 105), or 2 days postoperative physiotherapist-guided breathing exercises only without spirometer (PPB cohort, n = 114) were collected and analyzed. The acute or chronic collapse of part or entire lung was defined as atelectasis. The length of stay in the hospital was from the day of admission to discharge. Patients of the PPN cohort had fewer numbers of incidences of atelectasis, dyspnea, and sweating >1 day after operations compared to those of the PPB and the PPP cohorts ($P < .05$ for all). The partial pressure of oxygen and oxygen saturation of arterial blood ≥6 hours after operations reported higher, the duration of ventilation was shorter, and numbers of re-intubation processes reported fewer for patients of the PPN cohort than those of the PPB and the PPP cohorts ($P < .05$ for all). The hospital length of the stay of patients in the PPN cohort was fewer than those of the PPB and the PPP ($P < .0001$ for both) cohorts. Pre and postoperative nurse-guided incentive spirometry with a spirometer following cardiac surgeries would have better postoperative pulmonary outcomes and fewer hospital stays than those of postoperative-only or pre and postoperative physiotherapist-guided breathing exercises (level of evidence: IV; technical efficacy stage: 5).

Abbreviations: CI = confidence interval, day 0 = immediate postoperative conditions, PPB cohort = patients received 2 days of postoperative breathing exercises by physiotherapists without a spirometer, PPN cohort = patients received 2 days of preoperative and 2 days of postoperative nurse-guided incentive spirometry with a spirometer, PPP cohort = patients received 2 days of preoperative and 2 days of postoperative breathing exercises by physiotherapists without a spirometer, VAS = visual analog scale.

Keywords: atelectasis, breathing exercises, cardiac surgeries, dyspnea, hospital stays, incentive spirometry, sweating

1. Introduction

Postoperative pulmonary complications are common after cardiac surgery and the incidences of postoperative pulmonary complications are 30 to 60%.[1] Postoperative complications increase morbidities, mortality, and the cost of hospitalization.[1,2] Major postoperative complications that affect the quality of life of patients after cardiac surgery are atelectasis, pneumonia, bronchitis, respiratory insufficiency, pulmonary edema, and pleural effusion.[3]

Cardiac surgery itself is the main pathophysiological determinant atelectasis. Also, the administration of general anesthesia in cardiac surgeries, atelectasis (breathing problem) is the most occurring postoperative complication.[4] There is no specific etiology for atelectasis but general anesthesia, impaired diaphragm functions, chest wall shift, abdominal distension,

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

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pleural effusion, and pain may contribute to atelectasis.[1] Also, pain and postoperative fear associated with changes in lung mechanics can affect the performance of periodic deep inspiration and effective cough. This allows accumulation of secretion, and the collapse of the alveolar, and that affects exchanges of oxygen and carbon dioxide.[5]

Preoperative physiotherapist-led respiratory exercises, especially spirometry and/or deep breathing exercises led to decrease in postoperative complications, especially atelectasis, hospital stay, and pain.[1,6,7] However, the Cochrane review suggests that incentive spirometry has no benefits for postoperative complications after cardiac surgeries.[8] There is no clear clinical evidence for the reduction of postoperative complications after cardiac surgeries. The available strategies to decrease postoperative complications after cardiac surgeries are the increase of mobility of patients, expectorations of secretions, and restoration of functional residual capacity.[9] Besides these, deep-breathing exercises, early ambulation, and positive airway pressure are preferred to decrease postoperative complications after cardiac surgeries.[4,10]

A generally used technique to decrease postoperative complications after cardiac surgeries are deep-breathing exercises.[11] Deep-breathing exercises or incentive spirometry is generally used postoperatively for effective inspiration. Patients who experienced incentive spirometry generally have positive feedback.[12] Incentive spirometry reduces pleural tension, enhances lung expansibility, and improves ventilation-perfusion.[1] Moreover, atelectasis could be reversed by repeated incentive spirometry procedures.[13]

Incentive spirometry is reported to decrease incidences of postoperative complications and hospital stays in abdominal surgeries[14] and pulmonary surgeries.[7,15] However, available studies reported questionable results of incentive spirometry on postoperative complications.[16] Additionally, the study reported that patients who had performed deep-breathing exercises may have fewer postoperative complications after abdominal surgeries.[17] Additional research is required to clarify the necessity of postoperative incentive spirometry procedure.[8,16,18] Staff nurses and respiratory therapists are generally involved in incentive spirometry procedures. Staff nurses or respiratory therapists teach instructions of incentive spirometry to patients.

Besides postoperative incentive spirometry procedures, preoperative health-oriented education makes patients prepare for surgeries and decreased postoperative complications.[19] Over and above postoperative incentive spirometry procedure, preoperative parameters, for example, oxygenation also have an association with postoperative complication rates.[20–22] Preoperative incentive spirometry procedures and preoperative breathing exercises decrease postoperative pneumonia and atelectasis after coronary artery bypass grafting.[1,23] Pre and postoperative incentive spirometry procedure improves lung capacity for inspiration and arterial oxygenation among patients following coronary artery bypass grafting.[1] However, the preoperative incentive spirometry procedure is reported ineffective in postoperative complications among patients following coronary artery bypass grafting.[24] All in all, there is a need for evaluation of the effects of pre and postoperative incentive spirometry procedures on postoperative complications following cardiac surgeries.

The objectives of the monocenter, 3-arm, retrospective study were to evaluate postoperative complications and length of hospital stay of patients who received pre and postoperative nurse-guided incentive spirometry against those of patients who received pre and postoperative or postoperative-only breathing exercises by the physiotherapist in patients who underwent cardiac surgery.

2. Patients and methods

2.1. Ethics approval and consent to participate

The designed protocol (GMU15245 dated January 15, 2020) has been approved by the human ethics committee of the Xingtai People's Hospital and the nursing society of China. The study follows the law of China and the V2008 Declarations of Helsinki. Written informed consent was signed by all participants before non-treatment interventions. Being a retrospective analysis informed consent and consent to participate were waived for publication of the study.

2.2. Inclusion criteria

Patients who received any kind of nonintervention after and/or before every kind of cardiac surgery to decrease postoperative complications are included in the study analysis.

2.3. Exclusion criteria

Patients with incomplete data, patients with preexisting respiratory disorders (asthma, chronic obstructive pulmonary diseases), patients with >45 days of mechanical ventilation after cardiac surgery, patients with preexisting lung infection (pneumonia), and patients with pulmonary tuberculosis were excluded from the study.

2.4. Sample size calculation

At 80% power, $\beta = 0.1$, and $\alpha = 0.05$, a total of 100 was the sample size (minimum patients required in each cohort). Atelectasis has been used as a basis for calculating the sample size.

2.5. Interventions

A total of 102 patients received 2 days of preoperative and 2 days of postoperative nurse-guided incentive spirometry with a spirometer (SH-6082, Romsons Respirometer, Delhi, India, PPN cohort). A total of 105 patients received 2 days of preoperative and 2 days of postoperative breathing exercises by physiotherapists without a spirometer (PPP cohort). A total of 114 patients received 2 days of postoperative physiotherapist-guided breathing exercises only without a spirometer (PPB cohort). Besides these procedures patients of all cohorts received preoperative surgeries-related education from nurses as physiotherapist is consultant in institutes. On the availability of physiotherapist or nurse intervention was selected. Postoperative physiotherapist-led breathing exercises only is well-established. Therefore, it was control intervention.

2.6. Preoperative education

Preoperative surgeries-related education was provided by the nursing staff of the institute about what would happen in each stage of surgery. This education was provided through methods of expression, written materials, and/or standard forms of foundation.

2.7. Incentive spirometry

Patients were asked to hold their breath to raise the ball to the upward position at least for 5 seconds followed by normal expiration. Such as 10 breaths/session for 10 to 15 minutes with a spirometer. A total of 6 sessions/day.

2.8. Breathing exercises

Patients were asked to hold their breath at least for 5 seconds without a spirometer followed by normal expiration. Such as 10 breaths/session for 10 to 15 minutes without a spirometer. A total of 6 sessions/day.

2.9. Outcome measures

1.2.9. Preoperative parameters. Clinical and demographical characters and hemodynamic parameters were collected from hospital records of patients.

2.2.9. Hemodynamic parameters. Hemodynamic parameters (systolic blood pressure, diastolic blood pressure, and heart rate) were measured using a patient monitor (Intellivue MP60, Philips, Amsterdam, Netherlands). Intra and postoperative amount of blood loss and fluid resuscitation were evaluated and compared.

3.2.9. Anesthesia protocol. A total of 0 to 8% sevoflurane (ULTANE®, AbbVie Inc. New York, NY) in 100% oxygen (Jiaye Technology [Dongtai] Co., Ltd., China) and fresh air for 3 L/min was administered for 5 minutes through a face mask (Romsons International Noida, UP, India). A total of 2 mg/kg intravenous propofol (Diprivan, Fresenius Kabi, Bad Homburg, Germany) was administered. A total of 1.5 to 2 mg/kg rocuronium (Norcuron, Organon [China] Ltd., Beijing, China) with 2 to 20 μg/kg fentanyl (Daiichi Sankyo Ltd., Tokyo, Japan) was given. Anesthesia was maintained with 0 to 3% sevoflurane in 50% oxygen and 50% fresh air. A total of 0.3 μg/kg atracurium (Daiichi Sankyo Ltd., Tokyo, Japan) and 1 to 2 μg/kg/h fentanyl were given through surgery. A total of 0.3 to 0.6 mg/kg ethomidate (Daiichi Sankyo Ltd., Tokyo, Japan) was used for patients with left main coronary diseases and decreased ejection fraction.

2.10. Primary outcomes

1.2.10. Complications. Respiratory complications that occurred within 3 days after surgeries were evaluated. Atelectasis, pneumonia, pleural effusion, pneumothorax, and dyspnea were evaluated by chest X-rays, computed tomography, signs, and other symptoms.[2] The decision about the presence of atelectasis is based on the opinion of radiologists. Sweating on the face, palms, armpits, and/or abdominal-lumbar area were considered as sweating. Sweating results were based on physicians' opinions.

2.2.10. Atelectasis. The acute or chronic collapse of part or entire lung was defined as atelectasis.[1]

3.2.10. Dyspnea. An intense tightening in the chest, air hunger, difficulty breathing, breathlessness, or a feeling of suffocation were defined as dyspnea.

2.11. Secondary outcomes

1.2.11. Hospital length of the stay. The length of stay in the hospital was from the day of admission to discharge.[25]

The other parameters, for example, mechanical ventilation duration, oxygenation status, and pain intensity (visual analog scale [VAS], 0: absent pain, 10: maximum possible pain) were evaluated. Pain intensity was evaluated 3 days after the surgeries by the nursing staff of the institutes.

2.12. Statistical analysis

InStat 3.01, GraphPad Software (San Diego, CA) was used for statistical analysis purposes. Variables are depicted as median (quartile range) or frequency (percentage). For categorical variables, the chi-square test (χ^2 test) or Fisher exact test was used for statistical analysis. Kolmogorov–Smirnov test was used to check the linearity of continuous variables. Bartlett test was used to check whether standard deviations were distributed equally or not. One-way analysis of variance was used for linear variables with linear standard deviations. Kruskal–Wallis test or Mann–Whitney test was used for non-linear variables. Tukey or Dunn multiple comparison tests were used for post hoc analysis. All results were considered significant if the P value was <.05.

3. Results

3.1. Study population

From January 17, 2019 to September 15, 2022, a total of 386 patients underwent cardiac surgeries at the Xingtai People's Hospital, Xingtai, Hebei, China, and the referring hospitals. Among 386 patients, 42 patients had incomplete data, 2 patients had preexisting respiratory disorders, 11 patients had >45 days of mechanical ventilation after cardiac surgery, 1 patient had preexisting lung infection (pneumonia), and 9 patients had pulmonary tuberculosis. Therefore, data from these patients (n = 65) were excluded from the study. Data regarding postoperative complications and the length of hospital stay of a total of 321 patients were included in the analysis. The summary chart of the study is presented in Figure 1.

3.2. Preoperative characteristics

There are no significant differences in age, gender, ethnicity, body mass index, co-morbidities, and patients' behavior among cohorts ($P > .05$ for all, Table 1). Before surgeries atelectasis, pneumonia, pleural effusion, and pneumothorax were not reported in any of the patients. Before surgeries, there were no significant differences in the hospital stay (preoperative hospital stays) of patients among cohorts ($P > .05$). Ethomidate or propofol used within the 3 cohorts were comparable. Coronary artery bypass grafting or valve or both types of surgery were performed for patients. Type of surgeries, length of surgeries, and off/on pumps were comparable between cohorts. All patients received all planed interventions in all cohorts.

3.3. Hemodynamic parameters

There are no significant differences in hemodynamic parameters (systolic blood pressure, diastolic blood pressure, and heart rate) before and after anesthesia among cohorts ($P > .05$ for all). Intra and postoperative amount of blood loss and fluid resuscitation were comparable among cohorts ($P > .05$ for all).

3.4. Postoperative complications

1.3.4. Atelectasis. On immediate postoperative conditions (day 0), there was no atelectasis in any patient of any cohort. A total of 91 (28%), 118 (37%), and 32 (10%) patients on the first day after the operation, on the second day after the operation, and on the third day after the operation, respectively faced atelectasis. On the first day after the operation, 37 (32%), 34 (32%), and 20 (20%) patients from the PPB, the PPP, and the PPN cohorts, respectively faced atelectasis. Incidences of atelectasis events were higher in the PPB ($P = .0439$, 95% confidence interval [CI], [using the approximation of Katz]: 0.4634–0.9988, Fisher test) and the PPP ($P = .0405$, 95% CI: 0.4736–1.008, Fisher test) cohorts than that of the PPN cohorts on the first day after the operation. On the second day after the operation, 51 (45%), 41 (39%), and 26 (25%) patients from the PPB, the PPP, and the PPN cohorts, respectively faced atelectasis. Incidences of atelectasis events were higher in the PPB ($P = .0009$, 95% CI: 0.4091–0.8154, Fisher test) and the PPP ($P = .0391$, 95% CI: 0.5103–1.001, Fisher test) cohorts than that of the PPN cohort on the second day after the operation. On the third day after the operation, 2 (2%), 17 (16%), and 13 (11%) patients from the PPB, the PPP, and the PPN cohorts, respectively faced atelectasis. Incidences of atelectasis events

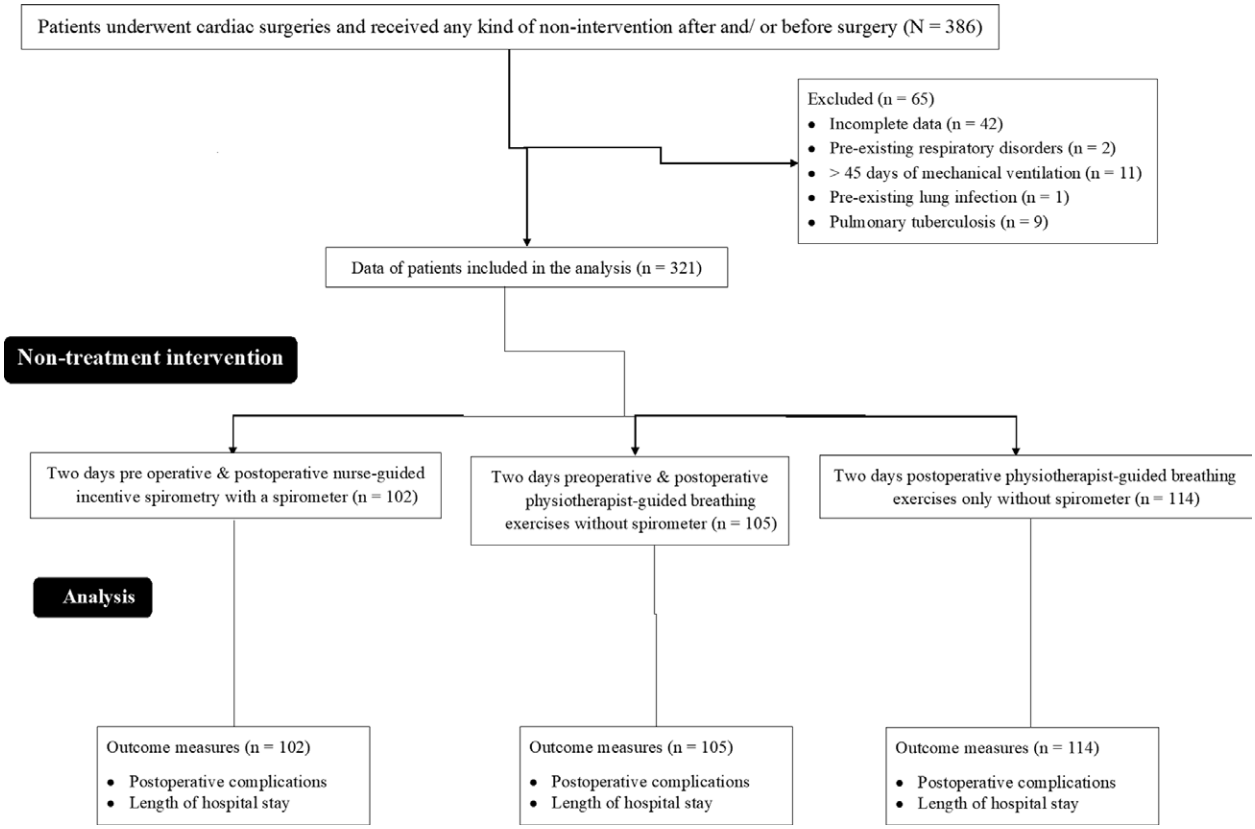

Figure 1. The summary chart of the study.

were higher in the PPB ($P = .0136$, 95% CI: 0.07680–1.031, Fisher test) and the PPP ($P = .0004$, 95% CI: 0.05297–0.7394, Fisher test) cohorts than that of the PPN cohort on the third day after the operation. However, incidences of atelectasis events were statistically similar in the PPB and the PPP cohorts on the first day ($P = .9999$, 95% CI: 0.7431–1.341, Fisher test), the second ($P = .4941$, 95% CI: 0.6694–1.187, Fisher test), and the third day ($P = .3306$, 95% CI: 0.8591–1.724, Fisher test) after the operation. The details of incidences of atelectasis events are reported in Figure 2.

2.3.4. Dyspnea. A total of 19 (6%), 43 (13%), 55 (17%), and 42 (13%) patients in postoperative condition (day 0), on the first day after the operation, on the second day after the operation, and the third day after the operation, respectively faced dyspnea. There were no significant differences for postoperative dyspnea among patients of the cohorts on the postoperative conditions (day 0) and the first day after the operation ($P > .05$ for both, χ^2 test). However, on the second and third day after the operation, incidences of dyspnea were fewer among patients of the PPN cohort than those of the PPB and the PPP ($P < .05$ for all, Fisher test) cohorts.

3.3.4. Sweating. A total number of patients 36 (11%), 56 (17%), 79 (25%), and 53 (17%) in postoperative condition (day 0), on the first day after the operation, on the second day after the operation, and the third day after the operation respectively faced sweating. On the first, the second, and the third day after the operation, incidences of sweating were fewer among patients of the PPN cohort than those of PPB and the PPP cohorts ($P < .05$ for all, Fisher test).

A total of 0 (0%), 13 (4%), 23 (7%), and 11 (3%) patients on postoperative condition (day 0), on the first day after the operation, on the second, and the third, respectively faced pneumonia. A total of 0 (0%), 6 (2%), 10 (3%), and 3 (1%) patients in postoperative condition (day 0), on the first day after the operation, on the second, and the third, respectively faced pleural effusion. A total of 0 (0%), 5 (2%), 11 (3%), and 3 (1%) patients in postoperative condition (day 0), on the first day after the operation, on the second, and the third, respectively faced pneumothorax. There were no significant differences for postoperative pneumonia, pleural effusion, and pneumothorax among the cohort on the first, second, and third day after the operation ($P > .05$ for all, χ^2 test). The details of postoperative complications are reported in Table 2.

3.5. Hospital length of the stay

The intensive critical care unit stay of patients of the PPN cohort was fewer than those of the PPP and the PPB cohort ($P < .001$ for both, Kruskal–Wallis test/Dunn multiple comparison tests). The intensive critical care unit stay of patients of the PPP cohort was also fewer than those of the PPB cohort ($P < .001$, Kruskal–Wallis test/Dunn multiple comparison tests). Ward stays of patients were comparable among cohorts ($P = .0691$, Kruskal–Wallis test). The total hospital length of the stay of patients of the PPN cohort was fewer than those of the PPB and the PPP ($P < .001$ for both, Kruskal–Wallis test/Dunn multiple comparison tests) cohorts. Hospital length of the stay of patients of the PPP cohort was fewer than those of the PPB cohort ($P < .001$, Kruskal–Wallis test/Dunn multiple comparison tests). The details of hospital length of the stay of patients are reported in Table 3.

3.6. Duration of mechanical ventilation

The median time for mechanical ventilation of patients was 21 hours (minimum: 4 hours and maximum: 42 hours). Postoperative mechanical ventilation is less often needed within patients of the PPN cohort than those of the PPP and

Table 1

Preoperative demographic and clinical characteristics.

Characteristics		Total	Cohorts					
			PPN	PPP	PPB			
	Preoperative	Incentive spirometry or breathing exercise or none	Nurse-guided incentive spirometry	Physiotherapist-guided breathing exercises	None			
Two days of non-treatment interventions	Postoperative	Incentive spirometry or breathing exercises	Nurse-guided incentive spirometry	Physiotherapist-guided breathing exercises	Physiotherapist-guided breathing exercises	Comparisons		
Numbers of patients		321	102	105	114	*P* value	Df	χ^2/KW value
Gender	Male	176 (55)	57 (56)	55 (52)	64 (56)	.8274 (χ^2 test)	2	0.3789
	Female	145 (45)	45 (44)	50 (48)	50 (44)			
Age (yr)	Minimum	37	39	39	37	.9766 (ANOVA)	320	N/A
	Maximum	60	60	60	60			
	Median	49	49	50	49			
Ethnicity	Han Chinese	292 (91)	93 (91)	96 (91)	103 (90)	.9984 (χ^2 test)	4	0.1162
	Mongolian	26 (8)	8(8)	8(8)	10 (8)			
	Tibetan	3 (1)	1 (1)	1 (1)	1 (1)			
Body mass index (kg/m^2)	Minimum	22	23	22	23	.1176 (KW test)	N/A	4.281
	Maximum	30	28	30	30			
	Median	26	26	25	26			
Diabetic neuropathy		18 (6)	4 (4)	5 (5)	7 (6)	.7498 (χ^2 test)	2	0.5759
Hypertension		36 (11)	13 (13)	12 (11)	11 (10)	.769 (χ^2 test)	2	0.5254
Ischemic heart disease(s)		11 (3)	4 (4)	4 (4)	3 (3)	.8438 (χ^2 test)	2	0.3398
Percutaneous coronary intervention		12 (4)	4 (4)	3 (3)	5 (4)	.8315 (χ^2 test)	2	0.369
Smoker	Current smoker	14 (4)	5 (5)	5 (5)	4 (4)	.985 (χ^2 test)	4	0.3686
	Previous smoker	32 (10)	10 (10)	11 (10)	11 (10)			
	Nonsmoker	275 (86)	87 (85)	89 (85)	99 (87)			

Variables are depicted as median (quartile range) or frequency (percentage).

ANOVA = analysis of variance, Df = degree of freedom, KW = Kruskal–Wallis, N/A = not applicable, PPB = patients received 2 days of postoperative breathing exercises by physiotherapists without a spirometer, PPN = patients received 2 days of preoperative and 2 days of postoperative nurse-guided incentive spirometry with a spirometer, PPP = patients received 2 days of preoperative and 2 days of postoperative breathing exercises by physiotherapists without a spirometer.

Results were considered significant if the *P* value was <0.05.

the PPB cohorts ($P < .001$ for both, Kruskal–Wallis test/Dunn multiple comparison tests). The duration of ventilation was shorter in patients of the PPP cohort than those of the PPB cohort ($P < .001$, Kruskal–Wallis test/Dunn multiple comparison tests). Re-intubation processes were performed in 18 (6%) patients. The number of patients in which re-intubation processes performed was fewer for the PPN cohort than the PPB cohort ($P = .0059$, 95% CI: 0.02563–1.105, Fisher test). The numbers of patients in which re-intubation processes were performed were also fewer for the PPN cohort than the PPP cohort. However, it was not statistically significant ($P = .0651$, 95% CI: 0.03896–1.541, Fisher test). The details of the mechanical ventilation time and re-intubation process of patients of the different cohorts are reported in Table 4.

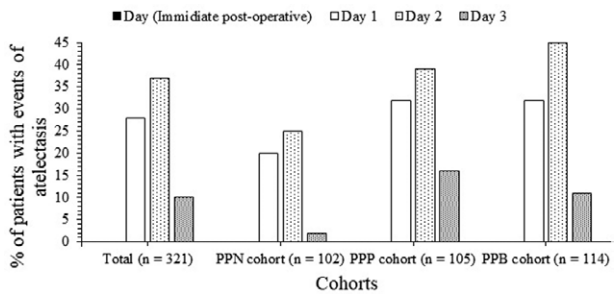

Figure 2. Atelectasis events after cardiac operation. Atelectasis: Acute or chronic collapse of part or the entire lung. Day 0 = immediate postoperative condition, Day 1 = 1 day after surgeries, Day 2: 2 days after surgeries, Day 3: 3 days after surgeries.

3.7. The partial pressure of oxygen

Preoperative ($P = .0877$, Kruskal–Wallis test), postoperative ($P = .1295$, Kruskal–Wallis test), 1 hour after operation ($P = .6805$, Kruskal–Wallis test), and 3 hours after operation ($P = .1164$, Kruskal–Wallis test), percentage partial pressure of oxygen of patients were the same among the cohort. For a total of 6 hours, 10 hours, 1 day, 2 days, 3 days, and 5 days after operations, patients of the PPN cohort had a higher percentage of partial pressure of oxygen than those of patients of the PPB and the PPP ($P < .001$ for all, Kruskal–Wallis test/Dann multiple comparison test) cohorts. However, 6 hours, 10 hours, 1 day, 2 days, 3 days, and 5 days after operations, patients of the PPB cohort had statistically the same percentage partial pressure of oxygen as those of the patients of the PPP cohort ($P < .05$ for all, Kruskal–Wallis test/Dann multiple comparison test). The percentage partial pressure of oxygen of patients at different time intervals is reported in Table 5. The increment of the percentage partial pressure of oxygen of patients concerning time is presented in Figure 3.

3.8. Oxygen saturation of arterial blood

Preoperative ($P = .14$, Kruskal–Wallis test), postoperative ($P = .0567$, Kruskal–Wallis test), and 1 hour after operation

Table 2

Postoperative complications.

Complications		Total	Cohorts					
			PPN	PPP	PPB			
	Preoperative	Incentive spirometry or breathing exercise or none	Nurse-guided incentive spirometry	Physiotherapist-guided breathing exercises	None			
Two days of non-treatment interventions	Postoperative	Incentive spirometry or breathing exercises	Nurse-guided incentive spirometry	Physiotherapist-guided breathing exercises	Physiotherapist-guided breathing exercises	Comparisons		
Numbers of patients		321	102	105	114	*P* value	Df	χ^2 value
Atelectasis	Day 0	0 (0)	0 (0)	0 (0)	0 (0)	N/A	N/A	N/A
	Day 1	91 (28)	20 (20)*	34 (32)	37 (32)	.0601	2	5.624
	Day 2	118 (37)	26 (25)*	41 (39)	51 (45)	.0123	2	8.792
	Day 3	32 (10)	2 (2)*	17 (16)	13 (11)	.0024	2	12.078
Pneumonia	Day 0	0 (0)	0 (0)	0 (0)	0 (0)	N/A	N/A	N/A
	Day 1	13 (4)	2 (2)	4 (4)	7 (6)	.2947	2	2.443
	Day 2	23 (7)	4 (4)	7 (6)	12 (11)	.1679	2	3.568
	Day 3	11 (3)	1 (1)	4 (4)	6 (5)	.2174	2	3.052
Pleural effusion	Day 0	0 (0)	0 (0)	0 (0)	0 (0)	N/A	N/A	N/A
	Day 1	6 (2)	1 (1)	2 (2)	3 (3)	.6699	2	0.8013
	Day 2	10 (3)	1 (1)	3 (3)	3 (3)	.5997	2	1.023
	Day 3	3 (1)	1 (1)	1 (1)	2 (2)	.8331	2	0.361
Pneumothorax	Day 0	0 (0)	0 (0)	0 (0)	0 (0)	N/A	N/A	N/A
	Day 1	5 (2)	1 (1)	1 (1)	3 (3)	.5179	N/A	1.316
	Day 2	11 (3)	2 (2)	4 (4)	5 (4)	.5988	2	1.026
	Day 3	3 (1)	1 (1)	1 (1)	1 (1)	.9964	2	0.0071
Dyspnea	Day 0	19 (6)	4 (4)	7 (7)	8 (7)	.5889	2	1.059
	Day 1	43 (13)	9 (9)	14 (13)	20 (18)	.1713	2	3.529
	Day 2	55 (17)	8 (8)*	22 (21)	25 (22)	.01	2	9.208
	Day 3	42 (13)	2 (2)*	17 (16)	23 (20)	.0002	2	17.066
Sweating	Day 0	36 (11)	4 (4)	7 (7)	10 (9)	.343	2	2.14
	Day 1	56 (17)	6 (6)*	20 (19)	30 (26)	.0004	2	15.888
	Day 2	79 (25)	9 (9)*	30 (29)	40 (35)	<.0001	2	21.406
	Day 3	53 (17)	3 (3)*	20 (19)	30 (26)	<.0001	2	22.078

Variables are depicted in frequency (percentage). The chi-square test was used for statistical analysis.

Day 0 = immediate postoperative condition, Day 1 = 1 day after surgeries, Day 2 = 2 days after surgeries, Day 3 = 3 days after surgeries, Df = degree of freedom, N/A = not applicable, PPB = patients received 2 days of postoperative breathing exercises by physiotherapists without a spirometer, PPN = patients received 2 days of preoperative and 2 days of postoperative nurse-guided incentive spirometry with a spirometer, PPP = patients received 2 days of preoperative and 2 days of postoperative breathing exercises by physiotherapists without a spirometer.

* Significantly fewer than those of the PPB and PPP cohorts.

Results were considered significant if the *P* value was <.05.

(*P* = .1543, Kruskal–Wallis test) percentage oxygen saturation of arterial blood of patients were the same among the cohort. At a total of ≥6 hours after operations, patients of the PPN cohort had a higher percentage oxygen saturation of arterial blood than those of patients of the PPB and the PPP (*P* < .05 for all, Kruskal–Wallis test/Dann multiple comparison test) cohorts. However, at a total of ≥6 hours after operations, patients of the PPB cohort had statistically the same percentage oxygen saturation of arterial blood as those of the patients of the PPP cohort (*P* > .05 for all, Kruskal–Wallis test/Dann multiple comparison test). The percentage oxygen saturation of arterial blood of patients at different time intervals is reported in Table 6. The increment of the percentage oxygen saturation of arterial blood of patients concerning time is presented in Figure 4.

3.9. Pain intensity

The VAS of patients of the PPN cohort was fewer than those of the PPB and the PPP cohorts. However, there were no statistically significant differences between the VAS of the PPN and the PPB cohorts (*P* = .5068, Mann–Whitney test). Also, the VAS of patients between the PPN and the PPP cohorts (*P* = .2354, Mann–Whitney test) were not statistically significant. The VAS of patients after 3 days of surgeries are reported in Table 7.

4. Discussion

The current study found that patients who received pre and postoperative nurse-guided incentive spirometry had fewer numbers of incidences of atelectasis on the first day, the second day, and the third day after surgeries compared to those who received postoperative physiotherapist-guided breathing exercises only or pre and postoperative physiotherapist-guided breathing exercises. Nurse-guided pre and postoperative use of the incentive spirometer would reduce the risk of postoperative pulmonary complications after cardiac surgeries.[5] Nurse-led treatment is superior to that of physiotherapist. Incentive spirometry using a spirometer is a mechanical tool that promotes proper lung expansion,[26] which physiotherapist-guided breathing exercises without a spirometer cannot do properly because of limited effects on the lungs.[3] Besides postoperative incentive spirometry or breathing exercises, the improvisation of preoperative pulmonary conditions of patients results in favorable postoperative lung outcomes.[3] Moreover, patients included in the

Table 3

Hospital length of the stay of patients.

Different types of stays in the hospital		Total	Cohorts			
			PPN	PPP	PPB	
Two days of non-treatment interventions	Preoperative	Incentive spirometry or breathing exercise or none	Nurse-guided incentive spirometry	Physiotherapist-guided breathing exercises	None	
	Postoperative	Incentive spirometry or breathing exercises	Nurse-guided incentive spirometry	Physiotherapist-guided breathing exercises	Physiotherapist-guided breathing exercises	Comparisons
Numbers of patients		321	102	105	114	*P* value / Kruskal–Wallis value
Intensive critical care unit stay (d)	Minimum	1	1	1	3	<.0001 / 162.13
	Maximum	8	4	7	8	
	Median	4	2*	4	5	
Ward stay (d)	Minimum	1	1	1	1	.0691 / 5.344
	Maximum	6	5	5	6	
	Median	3	3	3	3	
Total hospital stays (d)	Minimum	2	2	2	4	<.0001 / 129.77
	Maximum	13	8	11	13	
	Median	7	5*	7	8	

Variables are depicted as median (quartile range). Kruskal–Wallis test following Dunn multiple comparison tests was used for statistical analysis.

PPB = patients received 2 days of postoperative breathing exercises by physiotherapists without a spirometer, PPN = patients received 2 days of preoperative and 2 days of postoperative nurse-guided incentive spirometry with a spirometer, PPP = patients received 2 days of preoperative and 2 days of postoperative breathing exercises by physiotherapists without a spirometer.

*Significantly fewer than those of the PPB and PPP cohorts.

Results were considered significant if the *P* value was <.05.

Table 4

Mechanical ventilation time and re-intubation processes of patients.

Parameters		Total	Cohorts			
			PPN	PPP	PPB	
Two days of non-treatment interventions	Pre-operative	Incentive spirometry or breathing exercise or none	Nurse-guided incentive spirometry	Physiotherapist-guided breathing exercises	None	
	Post-operative	Incentive spirometry or breathing exercise	Nurse-guided incentive spirometry	Physiotherapist-guided breathing exercises	Physiotherapist-guided breathing exercises	Comparisons
Numbers of patients		321	102	104	114	*P* value / KW/χ^2 value
Mechanical ventilation time (h)	Minimum	4	4	6	10	<.0001 (KW test) / 196.42
	Maximum	42	21	33	42	
	Median	21	10*	22	35	
Re-intubation process		18(6)	1(1)*	7(7)	11(10)	.0245 (χ^2 test) / 7.421 (df: 2)

Variables are depicted as median (quartile range) or frequency (percentage).

df = degree of freedom, KW = Kruskal–Wallis, PPB = patients received 2 days of postoperative breathing exercises by physiotherapists without a spirometer, PPN = patients received 2 days of preoperative and 2 days of postoperative nurse-guided incentive spirometry with a spirometer, PPP = patients received 2 days of preoperative and 2 days of postoperative breathing exercises by physiotherapists without a spirometer.

*Significantly fewer than those of the PPB and PPP cohorts.

Results were considered significant if the *P* value was <.05.

study did not have a body mass index of >30 kg/m^2. Nonobese patients had less risk of atelectasis because positive end-expiratory transpulmonary pressure during general anesthesia is less.[27] The current study recommended pre and postoperative nurse-guided incentive spirometry for the reduction of incidences of atelectasis.

The current study found that patients who received pre and postoperative nurse-guided incentive spirometry had fewer numbers of incidences of postoperative dyspnea and sweating than those of patients who received postoperative physiotherapist-guided breathing exercises only or pre and postoperative physiotherapist-guided breathing exercises. Shrinking of the lungs and other mechanism related to the collapse of the lungs leads to dyspnea.[28] Sweating indicates stressful situations and emergencies which are controlled by the sympathetic nervous system.[29] Dyspnea and pulmonary edema are also responsible for sweating. Pre and postoperative incentive spirometry decrease the shrinking of the lungs which leads to decreased stress on the lungs for proper breathing. Therefore, pre and postoperative nurse-guided incentive spirometry had fewer numbers of incidences of postoperative dyspnea and sweating than physiotherapist-guided postoperative breathing exercises only or pre and postoperative breathing exercises.

The partial pressure of oxygen and oxygen saturation of arterial blood after the operation were reported higher, the duration of ventilation was shorter, and re-intubation processes were

Table 5

Percentage partial pressure of oxygen of patients at different time intervals.

Period		Total	Cohorts				
			PPN	PPP	PPB		
Two days of non-treatment interventions	Preoperative	Incentive spirometry or breathing exercise or none	Nurse-guided incentive spirometry	Physiotherapist-guided breathing exercises	None		
	Postoperative	Incentive spirometry or breathing exercises	Nurse-guided incentive spirometry	Physiotherapist-guided breathing exercises	Physiotherapist-guided breathing exercises	Comparisons	
Numbers of patients		321	102	105	114	*P* value	Kruskal–Wallis value
Preoperative (Day 0; %)	Minimum	84	85	85	84	0.0877	4.868
	Maximum	92	92	92	92		
	Median	88	87	88	88		
Postoperative (%)	Minimum	85	85	86	85	0.1295	4.089
	Maximum	92	92	92	92		
	Median	88	87	88	88		
1 h after the operation	Minimum	86	86	86	86	0.6805	4.7699
	Maximum	92	92	92	92		
	Median	88	88	88	88		
3 h after the operation	Minimum	86	87	86	86	0.1164	4.302
	Maximum	92	92	92	92		
	Median	89	89	89	88		
6 h after the operation	Minimum	86	88	88	86	<0.0001	63.925
	Maximum	93	93	92	92		
	Median	89	90*	89	89		
10 h after the operation	Minimum	86	90	87	86	<0.0001	116.5
	Maximum	94	94	92	92		
	Median	90	91*	89	89		
1 d after the operation	Minimum	87	90	88	87	<0.0001	149.22
	Maximum	95	95	92	92		
	Median	90	91*	89	89		
2 d after the operation	Minimum	87	90	88	87	<0.0001	174.14
	Maximum	95	95	92	92		
	Median	90	91*	89	89		
3 d after the operation	Minimum	87	90	88	87	<0.0001	171.82
	Maximum	96	96	92	93		
	Median	90	92*	89	89		
5 d after the operation	Minimum	87	91	88	87	<0.0001	173.63
	Maximum	97	97	92	93		
	Median	90	92*	89	89		

Variables are depicted as median (quartile range). Kruskal–Wallis test following was performed for statistical analysis.

Day 0 = immediate postoperative condition, PPB = patients received 2 days of postoperative breathing exercises by physiotherapists without a spirometer, PPN = patients received 2 days of preoperative and 2 days of postoperative nurse-guided incentive spirometry with a spirometer, PPP = patients received 2 days of preoperative and 2 days of postoperative breathing exercises by physiotherapists without a spirometer.

*Significantly higher than those of the PPB and PPP cohorts.

Results were considered significant if the *P* value was <.05.

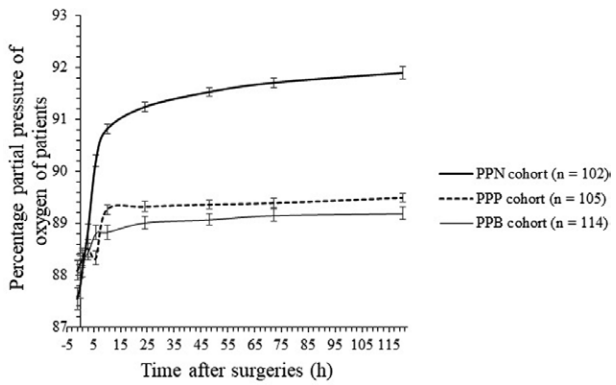

Figure 3. The increment of percentage partial pressure of oxygen of patients concerning time. Data are presented as mean ± standard error of the mean.

reported fewer if patients received pre and postoperative nurse-guided incentive spirometry following cardiac surgeries. Pre and postoperative nurse-guided incentive spirometry increases the partial pressure of oxygen and oxygen saturation of arterial blood after the operation because of proper lung expansion.[26] An increase in the gas exchange capacity of the lungs due to pre and postoperative nurse-guided incentive spirometry decreases mechanical ventilation requirements and time.[21] However, the other data regarding surgeries also have impact on postoperative pulmonary outcomes. For better postoperative pulmonary outcomes pre and postoperative nurse-guided incentive, spirometry would be preferred following cardiac surgeries.

Hospital length of stay was reported fewer for patients who received pre and postoperative nurse-guided incentive spirometry than those patients who received postoperative physiotherapist-guided breathing exercises only and of pre and postoperative physiotherapist-guided breathing exercises. Pre and postoperative incentive spirometry decrease mechanical ventilation time which lead to a decrease in a total hospital stay. However, other parameters like comorbidities of patients, limited available facilities in hospitals, experiences, and expertise of consultants, etc have effects on the hospital stay of patients.[20]

Table 6

Percentage oxygen saturation of arterial blood of patients at various levels.

Period		Total	Cohorts			Comparisons	
			PPN	PPP	PPB		
Two days of non-treatment interventions	Preoperative	Incentive spirometry or breathing exercise or none	Nurse-guided incentive spirometry	Physiotherapist-guided breathing exercises	None		
	Postoperative	Incentive spirometry or breathing exercises	Nurse-guided incentive spirometry	Physiotherapist-guided breathing exercises	Physiotherapist-guided breathing exercises		
Numbers of patients		321	102	102	114	*P* value	Kruskal–Wallis value
Preoperative (%)	Minimum	92	93	94	92	.14	3.933
	Maximum	99	99	98	98		
	Median	96	96	96	96		
Postoperative (%)	Minimum	93	93	94	93	.0567	5.741
	Maximum	99	99	98	98		
	Median	96	96	96	96		
1 h after the operation	Minimum	93	93	94	93	.1543	3.738
	Maximum	99	99	98	98		
	Median	96	96	96	96		
6 h after the operation	Minimum	93	93	94	93	.0005	15.148
	Maximum	99	99	98	98		
	Median	95	96*	95	95		

Variables are depicted as median (quartile range). Kruskal–Wallis test was performed for statistical analysis. PPB = patients received 2 days of postoperative breathing exercises by physiotherapists without a spirometer. PPN = patients received 2 days of preoperative and 2 days of postoperative nurse-guided incentive spirometry with a spirometer, PPP = patients received 2 days of preoperative and 2 days of postoperative breathing exercises by physiotherapists without a spirometer.

*Significantly higher than those of the PPB and PPP cohorts.

Results were considered significant if the *P* value was <.05.

Hospital length of stay would be decreased if patients will have received pre and postoperative nurse-guided incentive spirometry following cardiac surgeries.

Besides incentive spirometry or breathing exercises, all patients received preoperative surgeries-related education provided by nursing staff. Preoperative nursing education would make patients mentally and physically happy and operating results would become more favorable for patients.[19] Preoperative education is necessary for better postoperative outcomes.

Postoperative pain intensity was the same among all cohorts. The study results were not in line with a randomized trial.[1] Coughing and postoperative complications led to increasing pain intensity in patients.[1] Besides surgical procedures, the other parameters of patients, amount of pain-killer administered intra and postoperative conditions, amount of anesthesia, and type of anesthesia are all factors that affect postoperative pain.

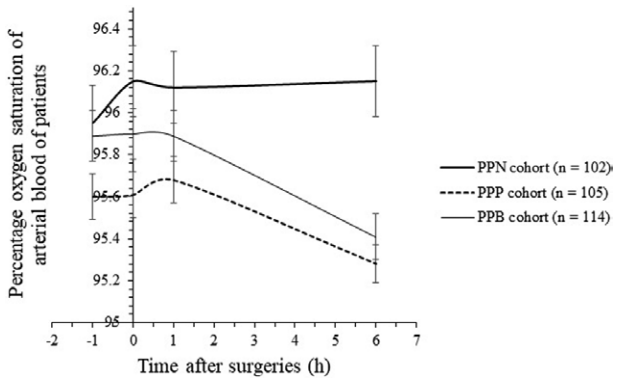

Figure 4. The increment of the percentage oxygen saturation of arterial blood of patients concerning time. Data are presented as mean ± standard error of the mean.

Pre and postoperative spirometry for 2 days is a "new design." However, there are limitations of the study, for example, retrospective analysis and lack of non-treatment randomized trials. Although incentive spirometry is reported effective on the gaseous exchange capacity of lungs[21] and lung expansion,[26] the study failed to report favorable effects of incentive spirometry on incidences of postoperative pneumonia, pleural effusion, and pneumothorax. Regarding your mechanical ventilation duration, most of the patients were mechanical ventilated at these time points. However, the ventilator settings (PEEP, FiO2, tidal/peak volume, and SpO2) were not compared between cohorts.

5. Conclusions

Pre and postoperative nurse-guided incentive spirometry had fewer numbers of incidences of postoperative atelectasis, dyspnea, and sweating than postoperative breathing exercises only or pre and postoperative breathing exercises following cardiac surgeries. Hospital length of stay and postoperative pain would be decreased if patients will have received pre and postoperative nurse-guided incentive spirometry following cardiac surgeries. Preoperative education is necessary for better postoperative outcomes. The current study recommended pre and postoperative nurse-guided incentive spirometry for the reduction of incidences of atelectasis.

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Author contributions

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Investigation: Hui Peng, Longfei Zhang.

Table 7

The visual analog scale of patients after 3 days after the surgeries.

Scale		Total	Cohorts				
			PPN	PPP	PPB		
Two days of non-treatment interventions	Preoperative	Incentive spirometry or breathing exercise or none	Nurse-guided incentive spirometry	Physiotherapist-guided breathing exercises	None		
	Postoperative	Incentive spirometry or breathing exercises	Nurse-guided incentive spirometry	Physiotherapist-guided breathing exercises	Physiotherapist-guided breathing exercises	Comparisons	
Numbers of patients		321	102	105	114	*P* value	Kruskal–Wallis value
VAS	Minimum	2	2	2	2	.0875	4.872
	Maximum	7	6	7	7		
	Median	3	3	3	3		

Variables are depicted as median (quartile range). Kruskal–Wallis test was performed for statistical analysis. 0: absent pain, 10: maximum possible pain.

PPB = patients received 2 days of postoperative breathing exercises by physiotherapists without a spirometer, PPN = patients received 2 days of preoperative and 2 days of postoperative nurse-guided incentive spirometry with a spirometer, PPP = patients received 2 days of preoperative and 2 days of postoperative breathing exercises by physiotherapists without a spirometer, VAS = visual analog scale. Results were considered significant if the *P* value was <.05.

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