The Effect of Method of Administering Incentive Spirometry on Postoperative Pulmonary Complications in Coronary Artery Bypass Patients

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We studied whether the method of administering incentive spirometry to cardiac patients after the immediate postoperative recovery period would affect the rate of postoperative complications. METHODS: Sixty subjects undergoing elective coronary artery bypass surgery were supported in the cardiac surgical unit (CSU) approximately 48 hours and then transferred to a general care area, where each was randomly assigned to one of three groups. Group-1 subjects received incentive spirometry treatments via a Spirocare device four times daily under therapist supervision. Group-2 subjects received four supervised treatments daily via a disposable Voldyne device. Group-3 subjects used the disposable Voldyne device with no therapist supervision after initial instruction. No comparison control group without breathing exercises was used because the subjects were considered to be at risk for pulmonary complications. Complications were monitored by temperature, cough productivity, and degree of atelectasis seen on chest radiographs for 3 days after transfer from the CSU. Incentive volumes and length of hospital stay were recorded. RESULTS: No significant differences in complication rates were found among the three groups on any of the 3 days after transfer from the CSU. CONCLUSION: We conclude that in the patient population and circumstances we studied, the method of administering incentive spirometry after transfer from intensive care does not affect the rate of pulmonary complications as indicated by incentive spirometry volumes, temperature, cough productivity, degree of atelectasis on chest film, or length of hospital stay. However, these preliminary findings should not be extrapolated to other populations or clinical circumstances until further studies have been carried out. (Respir Care 1988;33:771-778.)

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Introduction

Clinically important pulmonary complications such as atelectasis, pneumonia, and hypoxemia have been estimated to occur in 20-40% and even as high as 70% of patients following abdominal or thoracic surgery.[1,2] In the early 1970s, incentive spirometry was introduced to achieve a sustained maximal inspiratory maneuver as one method of preventing such postoperative pulmonary complications.[3,4] A number of studies have indicated that correctly utilized incentive spirometry, intermittent positive-pressure breathing (IPPB), and other deep-breathing maneuvers all are effective in reducing pulmonary complications.[5-11]

Patients undergoing open heart surgery can have a number of pre-existing risk factors, such as a smoking history and increased age, resulting in pulmonary complication rates of 60-84%.[7,12] In St Joseph's Hospital, a private institution affiliated with Georgia State University in Atlanta, coronary artery bypass graft patients with an uncomplicated course are routinely kept in the cardiac surgical unit (CSU) only 48 hours postoperatively, after which they are transferred to a general care area. Because they are still bedridden and considered to be at risk for pulmonary complications, incentive spirometry is routinely used in the 5-day period following surgery, which includes time in the ICU and further time in the general care area. If no complications occur, incentive spirometry is usually discontinued after the 5-day period. Because of the volume of cardiac surgery performed and because of an increasing shortage of respiratory care personnel, we investigated the effect on pulmonary complications in these patients when various methods were used to administer incentive spirometry.

In St Joseph's Hospital, nondisposable incentive spirometers such as the Spirocare* are not usually left in the patient's room between treatments. Disposable devices, on the other hand, would be assigned to a patient and would remain in his room. The question arose, Is there any difference in complication rates between patients with disposable incentive spirometers in their rooms and patients treated with the nondisposable Spirocare device? A second question was, Is there any difference in complication rates when disposable devices used for treatments attended by therapists are compared to completely unattended use (after the short period in the ICU)? We found nothing in the literature that addressed these questions, and the study reported here was designed to provide answers.

(Another question could be, Is there a difference in complication rates between post-cardiac surgery patients who receive incentive spirometry and those who do not? However, because our patients were considered to be at risk for such complications, and because breathing exercises have been shown to be effective in reducing such complications,[5-11] it would have been unethical to withhold incentive spirometry in a control group. Therefore, we did not study the question of whether incentive spirometry is better than no treatment to prevent pulmonary complications.)

Subjects and Methods

Population and Sample Selection

The study population was patients undergoing coronary artery bypass surgery. The population was further defined by the ability of subjects to meet the criteria for the use of incentive spirometry—namely, ability to achieve adequate spontaneous inspiratory volumes (usually a minimum of 50% of predicted inspiratory capacity), freedom from disorientation or extreme lethargy, and ability to cooperate. A sample of 60 subjects scheduled for elective (nonemergency) coronary artery bypass surgery at St Joseph's Hospital were invited to participate in the study. Patients scheduled for surgery on Fridays or Saturdays were excluded because they often lacked preoperative instructions in incentive spirometry, were on an emergency basis, and spent longer than usual periods in the ICU after recovery. Sample size was based on an estimated power of 0.8 or greater, at a significance level of 0.05. The study was approved by the hospital's Investigational Review Board, and written informed consent was obtained from all subjects prior to their participation.

Research Design

All subjects received standardized preoperative instructions in the performance of incentive

*Suppliers are identified in the Product Sources section at the end of the text.

spirometry. The protocol was the following: After exhalation to end-tidal volume, the subject was to inspire to total lung capacity and to hold his breath at least 5 seconds. This maneuver was to be performed 10 times, and the patient was to cough following the treatment.

After surgery, patients were recovered in the cardiac surgical unit (CSU) and received ventilator support for approximately 24 hours. Following extubation and while in the CSU, all patients received incentive spirometry via the nondisposable Spirocare device every 2 hours while awake; these treatments were attended by a respiratory therapist. Barring complications, on the third postoperative day the patients were transferred out of the CSU, and they were then randomly assigned to one of three groups. Group 1 used the Spirocare four times a day, with coaching by a respiratory therapist. Group 2 also received incentive spirometry four times a day and were coached, but they used a Voldyne disposable device. Group 3 used the Voldyne disposable device, but they were unattended after initial instruction following their transfer from the CSU. All subjects were encouraged to practice breathing deeply every hour, either spontaneously or by using the disposable devices at the bedside. One subject assigned to Group 3 (the unattended group) inadvertently received attended treatments, so the data represent 21 subjects in Group 2 and only 19 in Group 3.

Instruments and Measures

Incentive spirometry volumes were measured preoperatively and once a day postoperatively on each of three days after transfer from the CSU. All volumes were measured with a Wright respirometer that had been checked for accuracy with a 1-liter calibrating syringe prior to use. The respirometer was placed in-line between the spirometer and the patient's mouthpiece (Fig. 1), and an inhaled volume at ambient temperature and pressure was recorded. All measures were standardized by time of day, with two practice efforts by the patient prior to recorded measurements. An average of three measured volumes was used. The patients had had the measurement protocol demonstrated to them preoperatively, with both the Spirocare and the Voldyne devices. Except for the measurement period, the Group-3 subjects

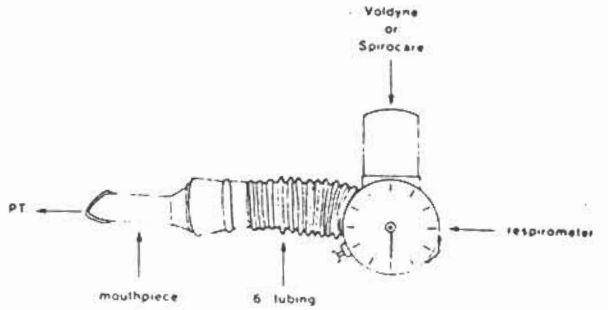

Fig. 1. Diagram illustrating placement of Wright respirometer to measure inspiratory incentive spirometry volumes.

were not attended by a therapist during use of the incentive spirometers.

Arterial blood gas values were obtained from most patients prior to surgery and from all patients at the time of transfer from the CSU, as part of routine patient care.

We also recorded each patient's oral temperature and cough productivity on the three days after transfer from the CSU, and we recorded the length of hospital stay. A chest radiograph was obtained on most patients 24, 48, and 72 hours after transfer from the CSU. A pulmonologist reviewed the radiographs for presence of atelectasis, using a graded scale of 0-5 to quantify the degree of atelectasis (Table 1). The physician was blind to patient group assignment when reviewing the chest films.

Data Analysis

Descriptive statistics, including frequency counts, the mean, and the standard deviation, were obtained to profile subjects in the three treatment groups. One-way ANOVA was used to test significance of differences among the three groups on spirometry volumes, temperature, and length of hospitalization.

Table 1. Scale Used to Quantify Relative Degree of Atelectasis on Chest Radiograph

0 - none
1 - minimal: less than one bronchopulmonary segment
2 - mild: 1-2 bronchopulmonary segments
3 - moderate: less than one lobe (upper or lower)
4 - severe: lobar or equivalent
5 - very severe: more than one lobe

The proportions of patients demonstrating productive cough were tested for significant differences by the chi-square statistic. Differences among the three groups for degree of atelectasis seen on chest films on each of the three days after transfer from the CSU were tested by the nonparametric Kruskal-Wallis ANOVA procedure. Data analyses were performed by the Statistical Package for the Social Sciences (SPSS) on a Unisys 1100 mainframe computer.

Results

Table 2 presents a description of the three treatment groups with respect to physical characteristics (age, height, weight, sex), history of smoking, and chronic obstructive pulmonary disease (COPD). Preoperative arterial blood gas values in the table were based on 15, 17, and 14 subjects in Groups 1, 2, and 3, respectively, reflecting patient availability. Arterial blood gas values at the time of transfer from the CSU represent all patients. The three groups showed similarity in all the variables measured.

Table 3 details differences among the three groups with regard to postoperative volumes, temperatures, length of hospitalization, and cough productivity. There were no significant differences among the groups for any of these values. The preoperative spirometry volumes in Table 3 are based on volumes from 10, 19, and 14 subjects respectively because not all subjects were available for preoperative testing. Figure 2 illustrates the similarity of spirometry volumes from the three groups on each of the three days following transfer from the CSU. The groups were compared for differences among volumes on each day, not by comparing change from baseline. A graph of the mean length of hospital stay for each group, in Figure 3, shows a shorter stay for the unattended group that used the Voldyne device, although hospital-stay values for the three groups were within 1 day of each other.

Table 4 shows the degree of atelectasis, as seen on chest films, for the three groups. The table entries are the numbers of patient with a given degree of atelectasis, as derived by use of the ranking scale described in Table 1. There were no significant differences among the three groups in degree of atelectasis on any of the three days after transfer from the CSU.

Table 2. Profiles of Subjects in Each of the Three Groups*

	Group 1: Attended Spirocare (n = 20)	Group 2: Attended Voldyne (n = 21)	Group 3: Unattended Voldyne (n = 19)
Age (yr)	62.4 ± 9.3	57.2 ± 9.4	57.8 ± 11.0
Height (inches)	67.8 ± 4.1	67.6 ± 4.3	68.3 ± 3.2
Weight (lb)	179.7 ± 34.7	169.9 ± 35.6	179.6 ± 27.7
Male	15	14	16
Female	5	7	3
Smoking (pk/yr)	23.8 ± 27.6	33.3 ± 34.6	29.1 ± 29.6
Range (pk/yr)	0-80	0-100	0-104
History of COPD	3/20 (15%)	5/21 (24%)	6/19 (32%)
Preoperative pH	7.46 ± 0.114	7.43 ± 0.022	7.43 ± 0.025
Preoperative P_{aO_2}	77 ± 20.8	84 ± 14.3	80 ± 13.5
Preoperative P_{aCO_2}	35 ± 3.1	36 ± 3.6	36 ± 4.7
Transfer pH	7.43 ± 0.04	7.42 ± 0.04	7.42 ± 0.04
Transfer P_{aO_2}	97 ± 17.8	98 ± 22.0	99 ± 25.2
Transfer P_{aCO_2}	41 ± 3.7	42 ± 4.6	41 ± 3.2

*Except for frequency counts, values are means ± standard deviations.

Table 3. Incentive Spirometry Volumes, Temperatures, Lengths of Hospital Stay, and Numbers of Patients with Productive Cough in the Three Groups*

	Spirocare	Voldyne Attended	Voldyne Unattended	
Preoperative Volumes	2.525 ± 0.478	2.421 ± 0.464	2.536 ± 0.308	
Postoperative Volumes				
Day 1	1.519 ± 0.370	1.338 ± 0.439	1.289 ± 0.351	NS† P = 0.173
Day 2	1.606 ± 0.352	1.489 ± 0.538	1.511 ± 0.489	NS P = 0.725
Day 3	1.888 ± 0.501	1.724 ± 0.603	1.782 ± 0.531	NS P = 0.639
Postoperative Temperatures				
Day 1	99.5 ± 0.8	99.2 ± 1.1	99.4 ± 0.8	NS† P = 0.547
Day 2	99.4 ± 1.0	99.4 ± 1.3	99.5 ± 0.9	NS P = 0.940
Day 3	99.2 ± 0.8	99.4 ± 0.9	99.0 ± 0.8	NS P = 0.527
Days of Hospitalization	8.8 ± 2.7	9.0 ± 2.4	8.1 ± 1.6	NS† P = 0.434
Productive Cough				
Day 1	1/20 (5%)	3/21 (14%)	2/19 (11%)	NS‡ P = 0.610
Day 2	3/20 (15%)	1/21 (5%)	2/19 (11%)	NS P = 0.548
Day 3	3/20 (15%)	1/21 (5%)	4/19 (21%)	NS P = 0.276

*Except for frequency, values are means ± standard deviations.

NS = not statistically significant.

†Tested by one-way ANOVA.

‡Tested by chi-square contingency table.

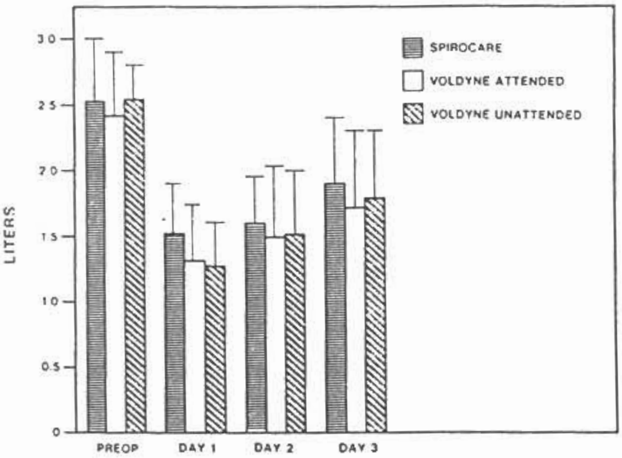

Fig. 2. Incentive spirometry volumes for each of the three groups preoperatively and on the three days following transfer from intensive care. Mean ± standard deviation.

Discussion

We consider the results of this study to be preliminary only. In particular, the lack of difference in pulmonary complications among the three treatment groups should not be overinterpreted as implying that all types of patients would fare favorably with unattended incentive spirometry. Our findings apply only to the specific type of patients we studied, under the conditions described. In the introduction we noted that cardiac surgery patients have a high rate of postoperative pulmonary complications.[12] The patients we studied received intensive care only for the relatively short period of 48 hours before transfer to a general care area. Unsupervised incentive spirometry cannot be recommended for other patient populations and situations without further investigation. The lack of a control group for comparison also limits interpretation of the results. Because the patients were considered to be at risk for complications when transfered from the CSU—for the reasons given above—and because incentive spirometry is considered effective in reducing the incidence of postsurgical pulmonary complications, a placebo group of human subjects was not acceptable. This changes the research question: Instead of asking whether incentive spirometry is of any benefit in the

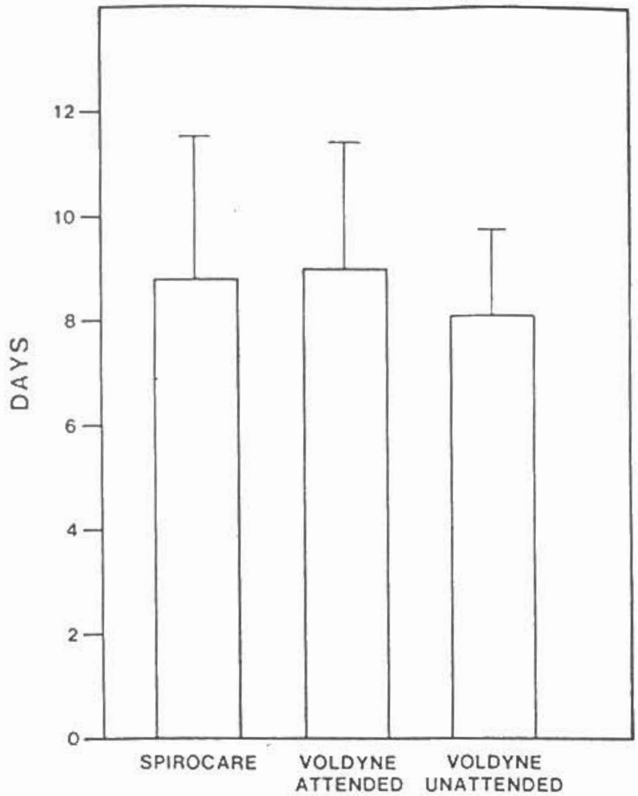

Fig. 3. Length of hospital stay for each of the three study groups. Mean ± standard deviation.

population and situation examined, the study could investigate only whether the method of administration matters when incentive spirometry is utilized. The lack of difference in pulmonary complications among the treatment groups could be due to the fact that breathing exercises were not needed at all, although we did not believe that to be the case with these patients. Resolution of this point would require further study with a control group. A study by Schwieger and others found an absence of benefit from incentive spirometry in low-risk elective cholecystectomy patients.[13] It should be understood that their subjects were at less risk than cardiac surgery patients by the criteria of selection and by the nature of the procedure.

A survey reported in 1985 by O'Donohue estimated that for both prophylaxis and treatment of atelectasis, incentive spirometry is prescribed in 95% of all American hospitals.[14] It is evident that many specific questions can arise concerning the use of incentive spirometry in particular situations. A clinical study of disposable and nondisposable incentive devices by Lederer and co-workers showed no differences in pulmonary function or respiratory complications among the devices used with a group of upper-abdominal surgical patients.[15] The devices were the Triflo II, the Bartlett-Edwards, and the Spirocare, all of which are flow-dependent. In that study, all patients were left unattended after initial instruction. Patients were monitored once daily for frequency and proper use on each of five postoperative days. However, the question of attended versus unattended use was not examined in the study. It was found that patients did not use any of the devices as frequently as prescribed. The investigators suggested that although a simple/inexpensive device was as effective as a more complex, expensive one, there should be frequent encouragement and reinforcement of instruction on each postoperative day. Actually, this recommendation was not based on any results in the study, since there was no comparison group that received completely attended use. We found no difference in complication rate between completely monitored use and use with once daily monitoring.

An interesting question is whether unattended patients do in fact perform prescribed deep breathing exercises with the frequency and effectiveness desired. It is difficult to determine whether patients are using unattended incentive devices without unintentionally changing the treatment to an attended one. If, during the daily check, patients are asked about frequency of use, the response may be inaccurate for several reasons. Patients may misrepresent frequency of use from a desire to please, they may simply not remember use, or in some cases they may not even realize which treatment is being questioned because of the confusing variety of nursing interventions. If they are asked to self-report use with some form of tally sheet or diary, then there is some form of monitoring, a 'projected presence' of the therapist, and this may affect frequency of use. Of course, misrepresentation can also occur on daily diaries. A study using devices that covertly record each patient use would be needed to investigate different use with different forms of monitoring. Our study did not investigate the question of frequency of use with the unattended group. Given that they were unattended, we examined the resulting complication rate. With the lack of difference among the three groups, it would be of interest to further examine habits of use in unattended groups, with various methods of monitoring, using a record-producing device as a check.

Table 4. Degree of Atelectasis Seen on Chest Radiograph for Patients in the Three Groups, on Each Day after Transfer from Intensive Care (Entries Are Number of Patients with Scale Value)

	Spirocare No. of Patients	Voldyne Attended No. of Patients	Voldyne Unattended No. of Patients	
Day 1				
0 - None	3	2	2	
1 - Minimal (< 1 segment)	1	3	3	
2 - Mild (1-2 segments)	7	11	7	*NS
3 - Moderate (< 1 lobe)	7	4	6	P = 0.747
4 - Severe (lobar)	1	1	1	
5 - Very Severe (> 1 lobe)	0	0	0	
No Chest Film	1	0	0	
Day 2				
0 - None	0	1	1	
1 - Minimal (< 1 segment)	5	1	6	
2 - Mild (1-2 segments)	6	10	5	NS
3 - Moderate (< 1 lobe)	8	8	6	P = 0.532
4 - Severe (lobar)	1	1	1	
5 - Very Severe (> 1 lobe)	0	0	0	
No Chest Film	0	0	0	
Day 3				
0 - None	1	2	3	
1 - Minimal (< 1 segment)	10	2	6	
2 - Mild (1-2 segments)	2	7	6	NS
3 - Moderate (< 1 lobe)	4	7	3	P = 0.081
4 - Severe (lobar)	0	1	0	
5 - Very Severe (> 1 lobe)	0	0	0	
No Chest Film	3	2	1	

*Significance of difference among 3 groups on each day tested using Kruskal-Wallis ANOVA for ranked observations.

Our study also indicates the need for further investigation of specific populations with different methods of administering incentive spirometry. The population defined here consisted of elective cardiac bypass patients who met requirements for use of incentive spirometry. The population included subgroups of smokers and COPD patients. To control for the possible differences due to these variables, subjects were randomly assigned to each of the three groups studied. As a result, information specific to these subgroups was lost. The question arises, Could cardiac bypass patients with concomitant diseases such as asthma, COPD, or restrictive lung defects perform equally well with unattended incentive spirometry? This question deserves further study comparing homogeneous groups of patients who have these problems.

Summary

The present study provides preliminary findings on the effect of different methods of administering incentive spirometry with regard to pulmonary complications in patients undergoing elective coronary artery bypass surgery. No differences in rate of pulmonary complications were seen with the different methods of incentive spirometry use. However a number of additional questions have been suggested by the results, requiring further investigation.

ACKNOWLEDGMENT

We thank Jon Hunt BS RRT for his inspiration to perform this study.

PRODUCT SOURCES

Disposable incentive spirometer:
Voldyne, Chesebrough Pond's Inc, Greenwich CT

Nondisposable incentive spirometer:
Spirocare, Marion Laboratories, Kansas City MO

Wright respirometer:
Haloscale compact, Ferraris Development & Eng Co Ltd, London, England

Calibration syringe:
Model #5530, Hans Rudolph Inc, Kansas City MO

Statistical package:
Statistical Package for the Social Sciences, SPSS Inc, Chicago IL

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