Research Report

The Effectiveness of Incentive Spirometry With Physical Therapy for High-Risk Patients After Coronary Artery Bypass Surgery

Background and Purpose. The purpose of this study was to determine whether the addition of incentive spirometry (IS) to postoperative pulmonary physical therapy is more effective than physical therapy alone in reducing postoperative pulmonary complications in high-risk patients after coronary artery bypass grafting (CABG). Patients were given the spirometer and instructed in its use, as often occurs in clinical settings. **Subjects.** Patients with chronic airflow limitation following CABG (N=185) participated. **Methods.** Subjects were randomly assigned to receive either postoperative pulmonary physical therapy (breathing exercises, secretion removal, mobility) or physical therapy combined with IS. **Results.** No difference was found between the two groups in atelectasis, spirometry, oxygen saturation, pulmonary infection, or hospital stay. **Conclusion and Discussion.** Incentive spirometry combined with physical therapy is no more effective than postoperative physical therapy alone in reducing atelectasis for this population. Use of the spirometer, however, was not monitored, and although the study mimicked practice as it often occurs, the effectiveness of the spirometer cannot be fully evaluated. [Crowe JM, Bradley CA. The effectiveness of incentive spirometry with physical therapy for high-risk patients after coronary artery bypass surgery. *Phys Ther.* 1997;77:260–268.]

Key Words: *Atelectasis, Coronary artery bypass, Pulmonary physical therapy, Spirometry.*

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Pulmonary complications in the period immediately following coronary artery bypass grafting (CABG) are a cause of morbidity.[1] Patients with preexisting pulmonary disease have been reported to be at increased risk for complications following surgery.[1–3] By contrast, Warner et al[4] reported no increased risk following CABG.

The effectiveness of physical therapy when provided routinely for patients following CABG has not been proven to be effective in decreasing morbidity.[5–7] Jenkins et al[7] concluded that the addition of breathing exercises or incentive spirometry (IS) to early ambulation, forced expiratory maneuvers, and coughing conferred no additional benefits to their patient population, whose average preoperative spirometric data indicated no airflow limitations. Stiller et al[5] also studied patients whose preoperative spirometric data indicated no airflow limitations. They reported that preoperative education, postoperative deep breathing exercises, and forced expiration maneuvers were not effective in reducing morbidity. Johnson et al[6] did not provide sufficient spirometric data to allow determination of whether their patients had airflow limitations. They reported that for those patients with minimal atelectasis at the time of extubation, the addition of sustained maximal inflations (SMI) to a routine of education, early ambulation, and deep breathing exercises did not reduce morbidity.[6] The outcomes of those patients with marked atelectasis at the time of extubation were not improved by the addition of percussion to a regimen of ambulation, deep breathing exercises, and SMI.[6]

Patients with preexisting pulmonary disease may have been included in these and other studies that evaluated the effectiveness of both IS and physical therapy, but their data were not analyzed separately. Smoking is a risk factor for the development of both coronary artery disease[8] and pulmonary diseases,[9] and many patients undergoing CABG demonstrate spirometric evidence of pulmonary disease.

Incentive spirometry is used frequently as a component of postoperative pulmonary management. Studies evaluating the effectiveness of IS in patients who have had cardiac surgery, however, have been unable to demonstrate the superiority of IS over breathing exercises,[7,10] early mobilization,[7,10] or intermittent positive pressure breathing.[11–13] In contrast, Oulton et al[14] compared the use of physical therapy alone with the use of physical therapy and each of two incentive spirometers and found that the group using an device requiring a preset volume goal had superior results.

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This study was approved by the Institutional Review Board of Hamilton Civic Hospitals.

Portions of this research were presented at the American Physical Therapy Association/Canadian Physiotherapy Association Joint Congress in Toronto, Ontario, Canada, in June 1994, and at the Royal College of Physicians and Surgeons of Canada meeting in Montreal, Ontario, Canada, in September 1995.

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Table 1.
Measurement Schedule

Measure[a]	Preoperative	Extubation	Day 2	Day 3	Discharge
Chest radiograph					
AP	X	X	X	X	
PA	X				X
Lateral	X				X
FEV_1, FVC	X	X	X	X	X
Oxygen saturation	X	X	X	X	X

[a] AP=anteroposterior, PA=posteroanterior, FEV_1=forced expired volume in 1 second, FVC=forced vital capacity.

Table 2.
Chest Radiograph Analysis

Scale	Finding
0	Clear or minor collapse, either unilaterally or bilaterally
1	Major collapse, either unilaterally or bilaterally
Yes/no	Pleural effusion
Yes/no	Pneumothorax
Yes/no	Pulmonary edema

The purpose of this study, therefore, was to investigate whether a combination of IS and physical therapy was more effective than physical therapy alone in decreasing postoperative complications in high-risk patients with chronic airflow limitation secondary to obstructive airways disease who were undergoing CABG.

Methods and Materials

Subjects

All patients who were scheduled for coronary artery bypass surgery alone (not associated with valve replacements or other procedures) between November 1991 and December 1993 underwent preoperative spirometry screening. Forced expired volume in 1 second (FEV_1) and forced vital capacity (FVC) were collected preoperatively. Patients who met the criteria for the study (FEV_1 of less than 70% of the predicted value, using prediction equations reported by Crapo et al,[15] and an FEV_1/FVC ratio of less than 0.8) were asked to participate in the study, and written informed consent was obtained. Patients who developed hemodynamic complications (eg, intraoperative myocardial infarction, major blood loss, marked hypotension, reduced cardiac output requiring the use of an intra-aortic balloon pump or extraordinary use of medications) in the operating room and those who were intubated longer than 72 hours following arrival in the cardiovascular intensive care unit (CV-ICU) were excluded.

Procedure

Eligible subjects received preoperative physical therapy, which included assessment of pulmonary status and associated risk factors and education about postoperative management. Postoperative physical therapy commenced on the first day in the CV-ICU. The therapist assessed the patients, and then assisted them in lung-expansion maneuvers (sustained maximal inspiratory maneuvers and bed mobility) and secretion-removal maneuvers (supported/assisted coughing). This management was provided once or twice per day by the physical therapist, and encouraged by other members of the health care team in the CV-ICU (nurses and respiratory therapists). Chest wall vibrations and percussions and suctioning were also done, if required. The frequency and content of physical therapy treatments and the encouragement by other staff members were provided similarly to all subjects in the trial. Patients were treated by the physical therapist more than once per day if they had at least one of the following signs: radiological evidence of lobar atelectasis, marked hypoxia, bilateral or extensive adventitious or bronchial breath sounds, or production of large amounts of sputum. After extubation, physical therapy management continued as described. Thoracic mobility and shoulder range-of-motion exercises commenced on the second postoperative day and were reinforced subsequently. As soon as possible, patients were assisted with ambulation (this was usually on the third postoperative day when the patients' cardiovascular status was stable). Physical therapy management also included education about self-monitoring and progression of activity.

At the time of extubation, normally in the first 24 hours postoperatively, subjects were assigned randomly to one of two treatment protocols, using a computer-generated random number table. Researchers[16,17] have reported a greater effect on pulmonary function for patients for whom the internal mammary artery was used for the bypass when compared with saphenous vein conduit. To ensure that subjects receiving the mammary artery conduits were equally distributed between the two treatment groups, separate randomization tables were used (prognostic stratification).

Group 1. Subjects who were randomly assigned to this group received only the postoperative physical therapy described.

Group 2. Subjects who were randomly assigned to this group received the physical therapy management described, and they were provided with an incentive spirometer* on the day of extubation, with directions for its use. This device is volume oriented, with a flow-monitoring component to encourage a sustained maximal inspiration. Nursing, respiratory therapy, and physical therapy staff were instructed to remind all subjects in group 2 to use the device hourly, but spirometer used was not successfully measured.

Measurements

The primary outcome measure chosen was atelectasis as estimated by chest radiography. Table 1 details the measurement schedule. Atelectasis, or collapse of the expanded lung, was evaluated using the scale shown in Table 2, which was based on previously described pulmonary radiographic evaluation methodology.[7] These measurements were read and categorized by a single observer, who was blind to the treatment allocation of the patient. This observer also noted the presence or absence of pulmonary edema, pneumothorax, and pleural effusion, because all of these sequelae can influence pulmonary function.

Secondary outcome measures included estimation of lung infection, oxygen saturation, and number of postoperative days in the hospital. Lung infection was determined to be present if there was a temperature at or above 38.5°C (using an Ivac tympanic technique), after the day of surgery, associated with a positive sputum culture. Increased temperature alone has not been demonstrated to be a reliable indicator of postoperative pulmonary complications.[18] Oxygen saturation was estimated noninvasively, using a pulse oximeter.† In the early postoperative phase, if the patient was using added oxygen, the pulse oximeter was removed for 15 minutes prior to assessment of oxygen saturation. If the patient desaturated below 88% while breathing room air, oxygen saturation was not measured. Pulse oximetry measurements have been found to correlate well with direct measurements of arterial oxygenation when saturations are above 80% (r=.878–.981).[19] Pulse oximeters consistently underestimate true saturation by 2.0% to 2.8%.[19] Nickerson et al[20] reported that changes of 1% in the saturation range above 90% and 2% in the range below 90% are indicative of clinical change.[20] The number of postoperative days in the hospital were extracted from each patient's hospital record, counting the day following surgery as the first postoperative day.

Table 3.
Preoperative Screening for Eligibility and Reasons for Nonentry

	No. of Patients
Underwent screening for eligibility	999
Did not meet spirometry criteria	800
Met spirometry entry criteria	199
Refused consent	2
Intraoperative complications	3
Marked bronchospasm, unable to do spirometry	1
Intubated >72 h	6
Randomly assigned to receive only physical therapy, given incentive spirometry by staff	2
Total eligible but not assigned to groups	14
Total eligible and randomly assigned to groups	185

Lung volumes (FEV_1, FVC) were also measured for the 3 days following extubation and prior to discharge because patients with radiologic evidence of atelectasis frequently have decreased lung volumes.[21] Spirometric measurements were taken with a portable spirometer,‡ with the patient seated or lying at a 45-degree incline, using standardized instructions. The best FEV_1 and FVC of three trials were recorded, not necessarily from the same trial. Forced expired volume in 1 second and FVC are among the most reliable of spirometric measures, with coefficients of variation of between 1.95% and 4.5% in asymptomatic individuals and slightly greater when associated with pathology.[20] Measurements obtained with pocket spirometers have been found to correlate highly with those obtained with the Vitalograph§ (r=.981 for FVC, r=.9491 for FEV_1).[22] When measuring FEV_1, the pocket spirometer underestimates the volume by 201 mL, when compared with the Vitalograph, the standard bellows type of spirometer used to measure these lung volumes.[22]

Data Analysis

Characteristics of the two groups at baseline were compared using unpaired two-tailed Student's t tests (age, FEV_1, FEV_1/FVC ratio, smoking pack-years) and chi-square tests (gender, use of internal mammary conduit, number of vessels bypassed, number of patients undergoing redo procedure, current smokers, current use of bronchodilators). Postoperative atelectasis in the two groups was analyzed for each day of measurement, using

* Voludyne 5000 spirometer, Sherwood Medical Co, 1915 Olive St, St Louis, MO 63103.

† Model 8500, Nonin Medical, 12900 Highway 55, Plymouth, MN 55441.

‡ Roxon Pocket Spirometer, Micro Medical Ltd, PO Box 6, Rochester, Kent, United Kingdom ME1 2AZ.

§ Vitalograph Ltd, 8347 Quivera Rd, Lenexa, KS 66215.

Table 4.
Preoperative Profiles of Study Patients[a]

Variable	PT Only	IS+PT	Test/Significance
Age (y)			
X̄	64.8	64.0	*t* test/*P*=.54
SD	8.6	8.9	
Range	42–83	38–78	
Gender			
Male (%)	79 (83%)	74 (82%)	χ^2/*P*=.87
FEV_1 (L)			
X̄	1.8	1.9	*t* test/*P*=.38
SD	0.5	0.5	
Range	0.49–2.68	0.71–2.8	
FEV_1/FVC ratio			
X̄	0.68	0.65	*t* test/*P*=.057
Range	0.18–0.79	0.43–0.73	
Vessels bypassed			
X̄	2.9	2.8	*t* test/*P*=.76
SD	0.8	0.9	
Range	1–5	1–5	
Conduit			
Internal mammary artery (%)	61 (64%)	58 (64%)	χ^2/*P*=.97
CABG: initial/redo			
Initial (%)	91 (96%)	85 (94%)	χ^2/*P*=.67
Smoking at time of surgery			
Yes (%)	9 (10%)	9 (10%)	χ^2/*P*=1.00
Pack-years			
X̄	30.6	31.0	*t* test/*P*=.91
SD	23	26	
Range	0–84	0–80	
Preoperative use of bronchodilators			
Yes (%)	21 (22%)	15 (17%)	χ^2/*P*=.40

[a] FEV_1=forced expired volume in 1 second, FVC=forced vital capacity, CABG=coronary artery bypass grafting, PT=physical therapy, IS=incentive spirometry.

Table 5.
Incidence of Atelectasis (Unilateral or Bilateral) Measured Radiographically[a]

	PT Only (n=95)	IS+PT (n=90)	Significance[b]
Preoperative	1/95 (1.0%)	0/90 (0%)	. . .[c]
Extubation*	9/95 (9.5%)	13/88 (14.8%)	*P*=.36
Day 2*	19/91 (20.9%)	15/84 (17.9%)	*P*=.73
Day 3*	11/49 (22.5%)	16/49 (32.7%)	*P*=.25
*Discharge**	*10/95 (10.5%)*	*9/89 (10.1%)*	*P*=.97

[a] Asterisk (*) indicates some missing data. Radiographs not always available for each subject daily. PT=physical therapy, IS=incentive spirometry.
[b] Significance based on chi-square test.
[c] Not significant; unable to calculate because of "0" in one cell and "1" in another cell.

chi-square tests. Radiologic evidence of pleural effusion, pneumothorax, and pulmonary edema was analyzed using a two-tailed Fisher's Exact chi-square test, as were incidence of postoperative infection and oxygen saturation. Student's *t* tests were used to compare days in the hospital.[23] A Mantel-Haenszel chi-square test was done to test the overall treatment effect.[24] A Breslow-Day test for homogeneity was performed to determine whether the treatment effect was similar between subjects with and without atelectasis at extubation. Subjects were stratified based on the presence or absence of pronounced atelectasis at the time of extubation. Two-by-two tables of treatment versus outcome were constructed for each subgroup. The Mantel-Haenszel procedure was used to test the average (summary) odds ratio over the two subgroups. The associated test of homogeneity of odds ratio over strata yielded the formal comparison of whether the treatment effect varied between strata. Risk reduction is computed as 1 minus the odds ratio. This is a measure of odds-ratio reduction or relative risk. A probability value of .05 was considered to be the limit of significance for all analyses.

Results

Nine hundred ninety-nine subjects who had CABG were screened for the study. The mean FEV_1/FVC ratio was 75.96 (SD=9.8, range=18–96), and the mean FEV_1 measured/FEV_1 predicted ratio was 80.3 (SD=17.8, range=13–133). One hundred ninety-nine subjects (19.9% of those screened) met the entry criteria for the study. One hundred eighty-five subjects entered the trial (for details of enrollment, see Tab. 3). Randomization was successful in that the two treatment groups were matched on all characteristics, and there were no differences on any of these factors (Tab. 4). One hundred fifty-three subjects had FEV_1/FVC ratios of less than 0.75, which is indicative of a greater degree of airflow limitation, and they were equally distributed between the two groups.

Table 5 shows the numbers and percentages of subjects in each treatment group with marked collapse or consolidation. A major degree of atelectasis is defined as unilateral lobar or bilateral segmental lung collapse. There was no difference between the groups. Figure 1 depicts the incidence of atelectasis graphically. Slightly more subjects in group 2 had pronounced collapse or consolidation at the time of extubation (14.8% versus 9.5% in group 1), but this difference was not statistically significant.

Pleural effusion (diagnosed radiologically) was a common finding postoperatively (Tab. 6). Pneumothorax and pulmonary edema (evident radiologically) were less common (Tab. 6). There were no differences between the two treatment groups on any of these findings at any time.

Secondary outcomes included number of postoperative days in hospital, incidence of infection, spirometry (FEV_1, FVC), and oxygen saturation. There was no difference between the two treatment groups on any of these outcomes (Tabs. 7 and 8, Figs. 2 and 3).

We assumed that subjects with marked atelectasis at the time of extubation may benefit to a greater degree from the intervention. In addition, there were slightly more subjects with pronounced atelectasis in group 2. A stratified analysis, therefore, was undertaken. Figures 4 and 5 differentiate between those subjects who, at the time of extubation and randomization, had little evidence of atelectasis and those with pronounced evidence of atelectasis. Two patients did not undergo chest radiography on the day of extubation and thus could not included in this analysis. In the 161 patients with minimal atelectasis at extubation, there was no benefit on day 2, as demonstrated by the addition of IS (Fig. 4). Very few of these subjects had atelectasis on the next day, and there was no difference between the two treatment groups. Among the 22 subjects with clinically important atelectasis on extubation, there was a risk reduction of 28% in group 2 by the next day (Fig. 5). For the subjects in group 2, there was a 22% risk reduction by the third day following extubation and a 54% risk reduction by

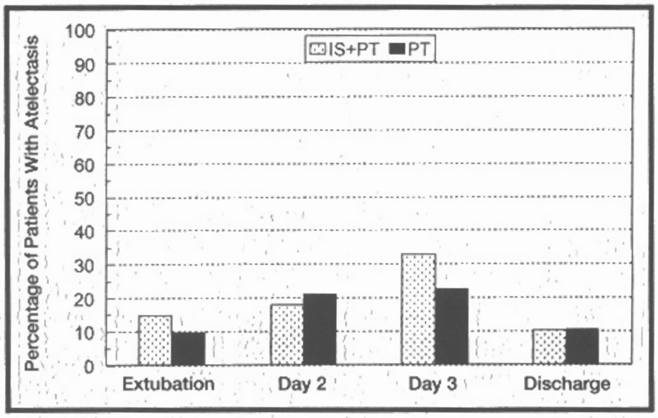

Figure 1.
Incidence of atelectasis measured radiographically. IS=incentive spirometry, PT=physical therapy.

the time of discharge. The test for homogeneity was not significant, indicating that the relative risk was not statistically significant, despite the trend. There was no association between those 22 subjects with marked atelectasis at extubation and those with an FEV_1/FVC ratio of less than 0.6, which indicates a greater degree of chronic airflow limitation secondary to obstructive lung disease.

Discussion

Maximal inflations of the lung increase production of surfactant, improve compliance and oxygenation,[25,26] and may assist in reexpansion of areas of atelectasis.[27] Clinical trials evaluating the management of postoperative complications have been plagued by small sample sizes, a lack statistical power to demonstrate a treatment effect, no consensus as to what constitutes a complication, and inadequate descriptions of the treatment. Trials that have failed to document the efficacy of routine postoperative physical therapy treatments have not included power calculations, which would enable the reader to detect a Type II error.[5–7]

Despite the lack of evidence, usage of IS for prophylaxis of atelectasis remains common and varies widely, between 44% in the United Kingdom and 95% in the United States.[28,29] Incentive spirometry is provided in combination with physical therapy in the United Kingdom, whereas its combination with physical therapy is less frequent in the United States.[28,29] The incentive spirometer used in our study cost $7.25, and if proven to be as effective as physical therapy, would be an economic alternative. The results of our study indicate that the use of incentive spirometers in addition to physical therapy is not cost-effective. In our study, the only difference between the two treatment conditions was the addition of the visual biofeedback device (incentive spirometer), which was designed to enhance patient compliance.

Table 6.
Numbers of Subjects With Radiographic Evidence of Pleural Effusion, Pneumothorax, and Pulmonary Edema[a]

	Extubation		Day 2		Day 3		Discharge	
	PT Only (n=95)	IS+PT (n=88)	PT Only (n=91)	IS+PT (n=84)	PT Only (n=49)	IS+PT (n=49)	PT Only (n=95)	IS+PT (n=89)
Pleural effusion	17	18	31	25	24	19	38	37
Pneumothorax	2	3	2	1	2	1	0	1
Pulmonary edema	2	3	2	2	0	3	3	4

[a] PT=physical therapy, IS=incentive spirometry.

Table 7.
Postoperative Morbidity of Study Patients[a]

Outcome	PT Only	IS+PT	Test/Significance
Postoperative days in hospital			
$\bar{X}$	9.7	9.0	*t* test/*P*=.22
SD	4.9	3.1	
Range	6–45	5–25	
No. of patients with postoperative infection (%)	10 (10.5%)	8 (8.9%)	χ^2/*P*=.71

[a] PT=physical therapy, IS=incentive spirometry.

Table 8.
Oxygen Saturation (Measured by Pulse Oximetry), Identifying the Number of Subjects With Saturation of Less Than 88% Without Supplemental Oxygen[a]

	PT Only	IS+PT	Test/Significance
Preoperative	0/89	0/84	. . .[b]
Extubation	51/83	45/87	χ^2/*P*=.45
Day 2	42/87	33/86	χ^2/*P*=.19
Day 3	21/86	17/85	χ^2/*P*=.25
Discharge	0/90	0/79	. . .[b]

[a] PT=physical therapy, IS=incentive spirometry.
[b] Unable to calculate because of "0" in at least one cell.

One explanation for the lack of difference in outcomes may be that subjects assigned to use the incentive spirometer did not comply. Our attempts to document patient compliance with the use of the incentive spirometer were not successful. All subjects in group 2 were provided with a form on which they and staff in the CV-ICU were asked to record use of the device each hour. Only 15 of the 90 subjects who were randomly assigned to receive the IS treatment documented any use. Subjects may have used the device as taught and failed to document utilization, or they may have used the device only minimally. Our study was designed to duplicate clinical practice, in which the patient is reminded by staff in the critical care unit to use the incentive spirometer as a visual cue to take maximal inspirations.

Our primary outcome was radiographic evidence of atelectasis on the second postoperative day, at which time the radiographs of 95% of the subjects were available. We included the data and analysis from subsequent days because they support the findings, but we realize that the evidence is not as strong. Radiographs were available for only 58% of subjects on the third postoperative day, although they were obtainable for 99.5% of the subjects by the time of discharge.

A control group with subjects receiving no postoperative physical therapy was not available, because such a protocol for patients considered to be at high risk would not have been approved by our institutional review board. The lack of differences in outcome between the two treatment groups (and especially in those subjects without marked atelectasis at extubation) may have been masked by the fact that the two treatments were not sufficiently different. This lack of differences in outcome could have been exacerbated by the apparent lack of compliance with use of the incentive spirometer.

Our study replicates previous studies in which the use of IS combined with postoperative pulmonary physical therapy was compared with the use of physical therapy alone in a population undergoing CABG. In contrast to previous studies, however, the inclusion criteria for our study included an FEV_1/FVC ratio of less than 0.8 and a measured FEV_1 of less than 70% of the predicted value. We were unable to find any benefit of IS combined with physical therapy over physical therapy alone in the management of these patients. Subjects who demonstrated preoperatively a more marked chronic airflow limitation were not more likely to develop marked atelectasis postoperatively.

The use of radiological evidence as a primary outcome has been used in many trials.[7,30] There is no standardized method of radiographic analysis, but in our study all radiographs were evaluated by one of the researchers, who is both a pulmonologist and an intensivist (board-certified in surgery, internal medicine, or anesthesia, with additional training in managing patients in inten-

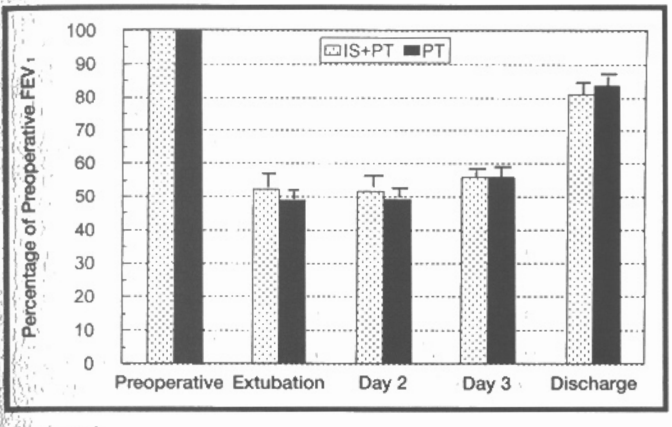

Figure 2.
Forced expired volume in 1 second (FEV_1) as a percentage of preoperative FEV_1. IS=incentive spirometry, PT=physical therapy.

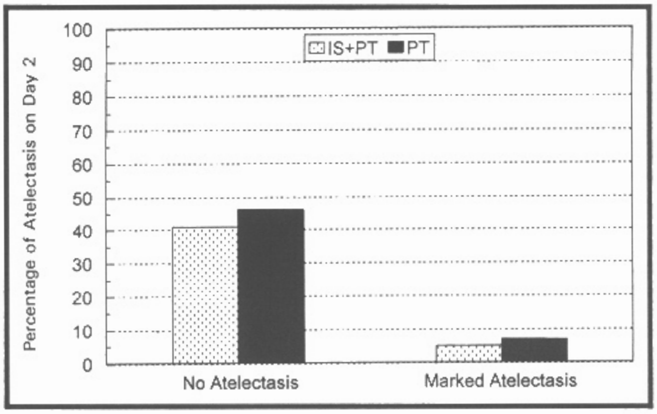

Figure 4.
Subjects with no atelectasis at extubation (n=161): effect on day 2 outcome. IS=incentive spirometry, PT=physical therapy.

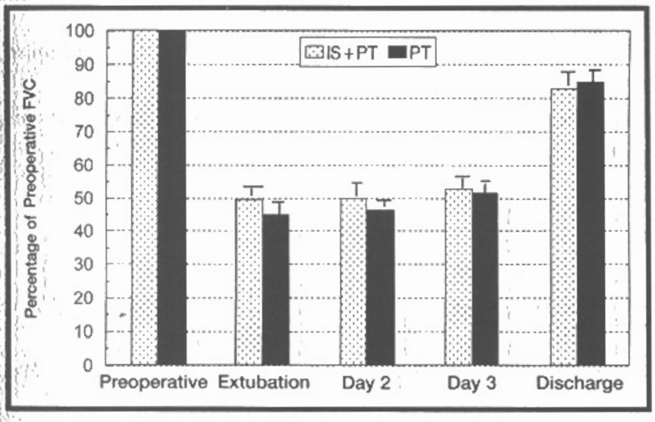

Figure 3.
Forced vital capacity (FVC) as a percentage of preoperative FVC. IS=incentive spirometry, PT=physical therapy.

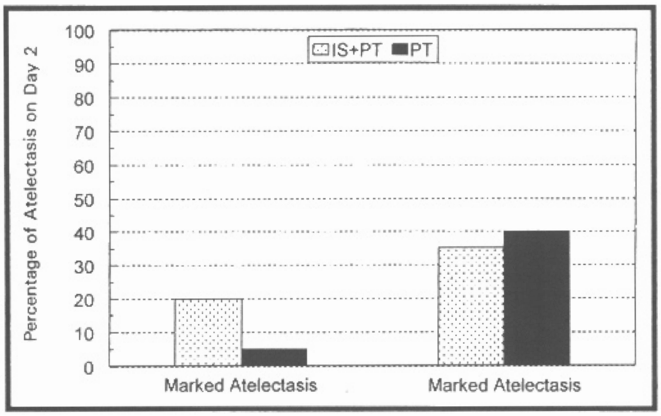

Figure 5.
Subjects with marked atelectasis at extubation (n=22): effect on day 2 outcome. IS=incentive spirometry, PT=physical therapy.

sive care). In our study, the incidence of pronounced atelectasis, either unilateral or bilateral, was measured because both can be of clinical significance.

If a true treatment effect reduces the rate of atelectasis by 50% (from the 21% in group 1), this study had a 47% power to detect this difference. Our study, therefore, may be considered slightly underpowered to detect a reasonable clinical effect.

The stratified analysis of those 22 patients with marked collapse at extubation showed a trend toward an added benefit of IS, with risk reductions above 22%, when compared with the analysis of those patients who received only physical therapy. This trend, however, failed to reach statistical significance and was not associated with poorer preoperative spirometry. This failure to reach statistical significance may have been due to the small number of subjects (n=22) with marked atelectasis at the time of extubation. The incidence of marked atelectasis was 10.8% overall, which was higher than the incidence of 5.7% with segmental lobe collapse reported by Warner et al.[31] The overall rate of pulmonary infection was 9.7%, between the overall rate of 2.6% reported by Warner et al[31] and the overall rate of 20% reported by Johnson et al.[6] Both the incidence of marked atelectasis and the overall rate of pulmonary infection may have been associated with the degree of chronic airflow limitation and smoking history of our subjects.

Conclusions

In order for incentive spirometers to be effective, they must be used regularly (four to five sustained maximal inspirations during each hour that the patient is awake).[30] An observation made by the physical therapists involved in this study was that the incentive spirometer was often placed out of the patient's reach and sight. Adherence to usage appears to be an issue. If further study sanctions the effectiveness of IS in some patient populations, a counter or alarm could be added to encourage adherence.

The results of our study add to the existing body of knowledge indicating that for the majority of patients with airflow limitation who undergo a CABG procedure, the addition of IS to physical therapy is not justified. The analysis indicates that for the small percentage of subjects (approximately 12% in this study) who exhibit marked atelectasis radiographically at the time of extubation, there may be an added benefit by the addition of IS to postoperative pulmonary physical therapy. Further study with a sufficient number of subjects is needed to establish whether the trend noted in our study is significant.

Acknowledgments

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