Incentive spirometry does not enhance recovery after thoracic surgery

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Objective: **To investigate the additional effect of incentive spirometry to chest physiotherapy to prevent postoperative pulmonary complications after thoracic surgery for lung and esophageal resections.**

Design: **Randomized controlled trial.**

Setting: **University hospital, intensive care unit, and surgical department.**

Patients: **Sixty-seven patients (age, 59 ± 13 yrs; forced expiratory volume in 1 sec, 93% ± 22% predicted) undergoing elective thoracic surgery for lung (n = 40) or esophagus (n = 27) resection.**

Interventions: **Physiotherapy (breathing exercises, huffing, and coughing) (PT) plus incentive spirometry (IS) was compared with PT alone.**

Measurements and Main Results: **Lung function, body temperature, chest radiograph, white blood cell count, and number of hospital and intensive care unit days were all measured. Pulmonary function was significantly reduced after surgery (55% of the initial value) and improved significantly in the postoperative period in both groups. However, no differences were observed in the recovery of pulmonary function between the groups. The overall score of the chest radiograph, based on the presence of atelectasis, was similar in both treatment groups. Eight patients (12%) (three patients with lobectomy and five with esophagus resection) developed a pulmonary complication (abnormal chest radiograph, elevated body temperature and white blood cell count), four in each treatment group. Adding IS to regular PT did not reduce hospital or intensive care unit stay.**

Conclusions: **Pulmonary complications after lung and esophagus surgery were relatively low. The addition of IS to PT did not further reduce pulmonary complications or hospital stay. Although we cannot rule out beneficial effects in a subgroup of high-risk patients, routine use of IS after thoracic surgery seems to be ineffective. (Crit Care Med 2000; 28:679–683)**

Key Words: pulmonary complications; thoracic surgery; breathing exercises; incentive spirometry; postoperative; respiration; physiotherapy; pulmonary function; lung surgery; esophagectomy

Postoperative pulmonary complications after thoracic and abdominal surgery are still a major cause of morbidity and mortality. Prolonged hospitalization and intensive care stay may result from this (1). Evidence for the effectiveness of physiotherapy in preventing postoperative pulmonary complications after abdominal surgery is provided in randomized controlled trials (2–5). There are, however, no data on the efficacy of physiotherapy after thoracic surgery. A recent meta-analysis confirmed the beneficial effect of physiotherapy on prevention of complications after abdominal surgery (6), but it remains unclear which treatment methods are most effective. In addition to deep breathing exercises, coughing, and early mobilization, accessory devices such as positive expiratory pressure mask breathing and incentive spirometry (IS) are provided to patients to reduce pulmonary complications. Although IS is used widely in clinical practice (7, 8), it has not been shown to be of additional value after major abdominal and cardiac surgery. No additional benefit was identified from IS in patients with coronary artery bypass grafting (9–12). After abdominal surgery, Hall et al. (13, 14) concluded that IS was as effective as chest physiotherapy in low-risk and high-risk patients. In low-risk patients after cholecystectomy, no benefit of IS was found compared with a control group not receiving any specialized respiratory care (15). Celli et al. (3) were also unable to detect differences in pulmonary complications (22%, on average) between deep breathing exercises, IS, and intermittent positive pressure breathing, but the patients in the IS group had a significantly shorter hospital stay.

Patients with thoracic surgery for lung or esophageal resections experience higher pulmonary complication rates than do patients after cardiac or abdominal surgery. One would therefore be more likely to observe additional effects of IS on the recurrence of pulmonary complications after lung and esophageal surgery. No data on the efficacy of IS to prevent postoperative pulmonary complications are available regarding this patient group. We performed the present study to investigate the potential benefit of additional IS on postoperative outcomes.

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MATERIALS AND METHODS

Seventy-four patients undergoing elective thoracic surgery for lung (n = 44) or esophagus (n = 30) resection were included in the study. The criteria used for patient selection were the ability to perform IS adequately and the ability to follow and understand preoperative instructions. Anthropometric and pulmonary function data are summarized in Table 1. Patients were randomized in either the physiotherapy plus IS group (IS group) or physiotherapy alone group (PT group). Spirometry was performed preoperatively and every other day after the surgery (days 3, 6, 9, and so on) until discharge from the hospital. Other investigations, such as chest radiography and laboratory investigations (white blood cell count and bacterial culture of sputum), were performed as frequently as judged clinically relevant by the pulmonary physician. Body temperature was determined from the daily recordings.

The institutional medical ethical board of the hospital waived the need for informed consent because IS was added to routine care.

Pulmonary Function Tests. All patients underwent preoperative spirometry with determination of forced expiratory volume in 1 sec and forced vital capacity. Spirometry was performed by using a portable spirometer (Microlab 3300; Micro Medical, Rochester, UK). The values obtained were related to the normal values of Quanjer et al. (16).

Respiratory Muscle Force. All patients underwent determination of maximal inspiratory pressure, P_{Imax}, and maximal expiratory pressure, P_{Emax}. These pressures were measured according to a modification of the method of Black and Hyatt (17). The modification consisted in the use of an electronic transducer instead of an aneroid manometer. P_{Imax} was measured from residual volume, RV, and P_{Emax} was measured near total lung capacity. Tests were repeated until three attempts differed by <5%. The highest values were taken for analysis.

Chest Radiograph Score. The postoperative chest radiographs were scored according the following rating (2): 0, no abnormalities; 1, minor atelectasis on one side; 2, minor atelectasis on both sides; 3, major atelectasis or infiltration on one side; and 4, major atelectasis or infiltration on both sides. These scores were determined by one observer who was blinded as to the treatment of the patient.

Pulmonary Complication Score. We defined a clinically significant pulmonary complication as the presence of an abnormal chest radiograph, elevated temperature with no focus outside the lungs, and increased infectious variables or positive signs for sputum microbiology (2, 13, 14, 18). We quantified this condition as follows: a chest radiograph score of ≥3, a white blood cell count of $>12 \times 10^3$, and a body temperature of >38°C (>100.4°F). Pulmonary edema (both cardiogenic and noncardiogenic) and pulmonary embolism were not considered a pulmonary complication for the purpose of this study (13, 14).

Treatment. Preoperatively, patients were instructed on breathing exercises, the use of IS (preferably twice), coughing, and pain management. The importance of early mobilization to prevent pulmonary complications was explained to the patient. The PT group was instructed to perform, every hour, two series of five to ten slow maximal inspiratory maneuvers with breath holding, followed by forced expirations and coughing. The IS group was instructed to perform, every hour, two series of five to ten slow maximal inspiratory maneuvers with the volume feedback incentive spirometer (Voldyne, Sherwood Medical, West Sussex, UK), followed by forced expirations and coughing.

Postoperatively, patients had optimal treatment for pain control with patient-controlled epidural analgesia. Patients were visited and treated by the physiotherapist once a day or more frequently when necessary. In the IS group, the target volume on the device was increased every day by the physiotherapist. Other treatment methods, such as postural drainage or endotracheal suctioning, were allowed as the physiotherapist and pulmonary physician judged necessary.

Statistics. Sample size of the study was calculated on the basis of a reduction of hospital stay to 2 days, 1 day to compensate for preoperative instruction of the proper use of IS and a 1-day reduction of postoperative hospital stay. From the data of Celli et al. (3), the SD of hospital stay was 3 days. With a power of 80% and a p of .05, 28 patients were needed in both groups.

Statistical analysis was performed on the data obtained in the 67 patients. All statistical analysis was performed using the SAS statistical package (SAS Institute, Cary, NC). Comparison of recovery of pulmonary function was analyzed with an analysis of variance for repeated measures considering interactions between time, treatment, and type of surgery. Frequency of abnormal chest radiography, elevated body temperature, and white blood cell count was analyzed with a chi-square test. Other comparisons between the IS and PT groups were performed with unpaired Student's t-tests. Limits of significance were set at $p < .05$.

Table 1. Anthropometric, lung function, and muscle strength variables (mean ± 1 SD)

	PT	IS
F/M (n)	6/29	5/27
Type of surgery, LS/ES (n)	20/15	20/12
Smokers (n)	29	28
Age (yrs)	61 ± 14	58 ± 13
Height (cm)	171 ± 8	171 ± 8
Weight (kg)	71 ± 13	79 ± 15[a]
BMI (kg/m^2)	24.4 ± 4.3	27.0 ± 5.9[b]
FEV_1 (% pred)	87 ± 25	99 ± 17[a]
FVC (% pred)	98 ± 19	106 ± 15
P_{Imax} (% pred)	77 ± 28	68 ± 28
P_{Emax} (% pred)	79 ± 26	79 ± 34

PT, physiotherapy; IS, incentive spirometry; F, female; M, male; LS, lung surgery; ES, esophageal surgery; BMI, body mass index; FEV_1, forced expiratory volume in 1 sec; FVC, forced vital capacity; P_{Imax}, maximal inspiratory mouth pressure; P_{Emax}, maximal expiratory mouth pressure.

[a]$p < .05$; [b]$p = .06$.

RESULTS

Sixty-seven of the 74 patients were eligible for analysis. Four patients who were selected for lung surgery decided not to undergo surgery or had their surgery elsewhere. Three patients in the esophageal surgery group developed acute respiratory failure immediately after surgery and could not be followed. Detailed information on patient characteristics is presented in Table 1. Patients were well matched between the two treatment regimens, except forced expiratory volume in 1 sec (% predicted) and body weight were significantly higher in the IS group ($p < .05$).

Pulmonary function was significantly reduced after surgery. On average, a loss of 55% of the initial value in forced vital capacity and forced expiratory volume in 1 sec was present in the total group (Fig. 1). The improvement in pulmonary function tests after operation was significant for both the IS group and the PT group ($p < .01$). No significant differences between the IS and PT groups were observed for the restoration of pulmonary function. After 3 wks, pulmonary function was still reduced compared with initial values. This was because of the design of our study. Patients discharged from the hospital were not covered by follow-up. Only patients with reduced pulmonary function and, consequently, delayed postoperative recovery had follow-up measurements.

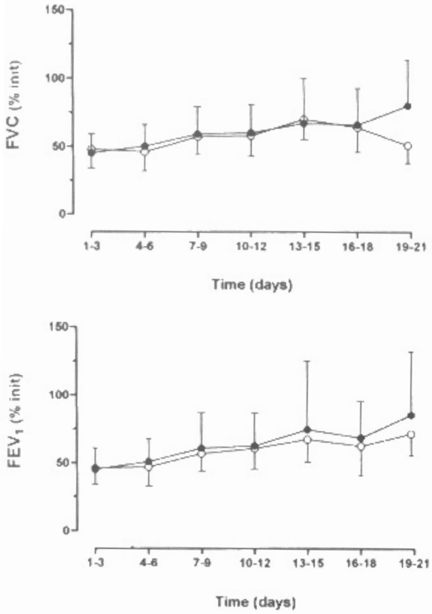

Figure 1. Recovery of the forced vital capacity (*FVC*, expressed as % of initial; *top*) and forced expiratory volume in 1 sec (*FEV_1*, expressed as % of initial; *bottom*) 1–3 days (n = 56), 4–6 days (n = 58), 7–9 days (n = 43), 10–12 days (n = 24), 13–15 days (n = 18), 16–18 days (n = 16), and 19–21 days (n = 9) after surgery in both patient groups. Solid circles, physiotherapy alone group; *open circles*, physiotherapy plus incentive spirometry group.

Eight patients (12%), four in each group, developed a pulmonary complication (Table 2). The pulmonary complication rate was significantly lower in cases of lung surgery (8%; three patients with lobectomy) compared with esophageal surgery (19%; five patients). Scores of chest radiograph, leukocytes, and body temperature were similar in the IS and the PT groups (Table 2). The number of days and the number of patients with an abnormal chest radiograph, leukocytosis, and fever were not different between the IS and the PT groups (Fig. 2). Minor abnormalities of the chest radiograph (score, 1 or 2) were 45 days (11 patients) for score 2 and 70 days (23 patients) for score 1 in the PT group and 61 days (8 patients) for score 2 and 45 days (17 patients) for score 1 in the IS group. This was significant for the number of events ($p < .01$) but not for the number of patients ($p = .97$).

When the effects of IS and physiotherapy were analyzed for lung resection and esophageal resection separately, again no differences were found. However, regardless of the intervention, a significant difference was observed for hospital stay, leukocytosis, chest radiograph, recurrence of pulmonary complications, and number of bronchoscopies, between lung and esophageal resection (Table 3).

Table 2. Mean (±SD) values for hospital stay and intensive care unit (ICU) stay, white blood cell count (WBC), chest radiograph score, body temperature, and number of bronchoscopies and pulmonary complications (PPC) in the incentive spirometry (IS) and physiotherapy (PT) groups

	PT	IS
Hospital stay (days)	15 ± 7	14 ± 8
ICU stay (days)	2.0 ± 3.4	2.5 ± 7.5
WBC ($\times 10^3$)	10.4 ± 3.1	10.7 ± 3.1
Chest radiograph	1.1 ± 1.0	1.2 ± 1.1
Body temperature (°C)	36.9 ± 0.4	37.1 ± 0.7
Bronchoscopy (n)	3	3
PPC (n)	4	4

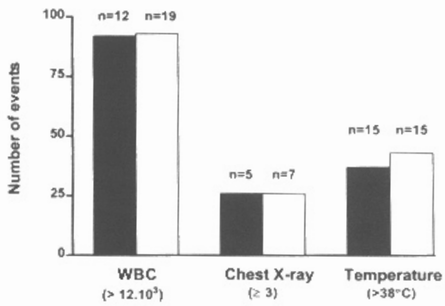

Figure 2. Number of events above the threshold values for chest radiograph (≥3), white blood cells (WBC; >12.10^3), and body temperature (>38°C) (>100.4°F). *Solid bars*, physiotherapy alone group; *open bars*, physiotherapy plus incentive spirometry.

DISCUSSION

The present data demonstrate that the postoperative pulmonary complication rate was relatively low after thoracic surgery for lung or esophageal resection. IS had no additional effect on the recovery of pulmonary function, pulmonary complications, and hospital stay.

In the present study, the pulmonary complication rate for lung resection (8%) was low compared with previous studies. Busch et al. (19) had 16% minor and 22% major pulmonary complication rates, and Issa et al. (20) had a complication rate of 60% in a group receiving chest physiotherapy, but 13% in a group that had additional hourly endotracheal suctioning through a minitracheotomy. Nagasaki and colleagues (21) observed complication rates of 8% in minor complications and 9% in major complications.

Higher pulmonary complication rates after esophageal surgery were found in the literature. Nagawa et al. (22) had pulmonary complications in 32% of their patients after transthoracic esophagectomy. These results are similar to those of Mäkelä and colleagues (23) but lower than transthoracic resections in high-risk patients (64%). Transhiatal resections had a substantially lower occurrence of pulmonary complications (14% and 25%, respectively) in the above-mentioned studies (22, 23). These numbers are higher than the complication rates in the present study (19%), in which only transthoracic resections were included.

Table 3. Mean (±SD) values for hospital stay and intensive care unit (ICU) stay, white blood cell count (WBC), chest radiograph score, body temperature, and number of bronchoscopies and pulmonary complications (PPC) in the esophagus surgery (ES) and lung surgery (LS) group

	ES	LS
Hospital stay (days)	18 ± 10	11 ± 5[a]
ICU stay (days)	4.0 ± 9.0	1.3 ± 2.0
WBC ($\times 10^3$)	11.3 ± 3.1	9.8 ± 2.2[a]
Chest radiograph	1.4 ± 0.8	0.8 ± 0.9[a]
Body temperature (°C)	36.9 ± 0.4	37.0 ± 0.5
Bronchoscopy (n)	3/27	3/40[a]
PPC (n)	5/27	3/40[a]

[a]$p < .05$, LS vs. ES.

The higher pulmonary complication rate, more abnormalities on chest radiograph, and leukocytosis in the esophageal resection group indicate the higher risk in these patients for postoperative morbidity. The longer duration of hospitalization is in accordance. These changes, however, should not necessarily be attributed to pulmonary complications, but could also be related to complications of the esophageal resection itself.

The present study could be criticized in some respects. First, the conclusion that pulmonary complications were relatively low in our study could be challenged. The definition of a pulmonary complication varies among studies and can substantially influence the complication rate. However, we tried to define a pulmonary complication as a clinically relevant condition resulting in additional effort and cost of medical care. In other studies, similar definitions, such as major pulmonary complication excluding pulmonary embolism and pulmonary edema, were used (2, 13, 24).

Second, patient characteristics may have influenced the outcome of the study. The small difference in pulmonary function between the two groups could have influenced the outcome of the

Postoperative pulmonary complication rate was relatively low after thoracic surgery for both lung and esophageal resection. The addition of incentive spirometry to physiotherapy did not further reduce pulmonary complications or hospital stay.

study. Pulmonary function is a significant risk factor in both lung (21) and esophageal (25) surgery. However, because the IS group had a better pulmonary function than the PT group, the hypothesis that IS reduces pulmonary complications would have enhanced differences between the groups. Because no differences in outcome were observed between the groups, the reduced pulmonary function in the PT group was probably not clinically relevant. In addition, body weight and body mass index (BMI) were higher in the IS group. Only for body weight did the difference reach statistical significance. The differences in BMI were small between groups and probably not clinically relevant, because a BMI of >27 kg/m^2 was found to be an independent risk factor predicting pulmonary complications after abdominal surgery (5, 26). Mean body mass in the patients who developed a pulmonary complication was 22.2 kg/m^2. No correlation was observed between BMI and length of hospital stay.

Third, the use of the incentive spirometers was not monitored and quantified to the number of efforts to control for patient compliance with the treatment. The use of breathing exercises and IS was supervised by the physiotherapist on a daily basis. Patients were encouraged to perform the exercises and target volume adjustments were made. However, we have no data to identify patients who were very strict in their exercises and patients who were less motivated.

Last, the study might be unable to accurately detect differences in hospital stay between groups. The mean, not statistically significant, difference in our study was 1 day (shorter in the IS group). Recalculation of the power with the data from the present study revealed that we should have included 609 patients in each group to find a significant reduction of hospital stay with 1 day. A one-day reduction in hospital stay in the IS group is not a clinically relevant difference because a longer hospital stay is needed before the surgery to instruct in the proper use of IS.

The lack of additional effect of IS is in accordance with previous studies in other patient groups after abdominal (13, 27, 28) and cardiac surgery (10–12) and is confirmed by two recent meta-analysis (6, 9). In patients after cardiac bypass surgery, Oulton et al. (29) observed significantly lower abnormal chest radiograph scores in patients who had volumetric IS compared with flow IS and physiotherapy. Hall et al. (14) compared the efficacy of breathing exercises and IS in a large group of patients with low and high risk for pulmonary complications undergoing abdominal surgery. They observed no differences in complication rate (~15% in both groups).

In patients with lung surgery, IS and inspiratory muscle training did not alter the pulmonary complication rate compared with a control group (30). Melendez et al. (31) observed a decrease of diaphragmatic contribution to tidal volume during IS in patients after thoracotomy.

The lack of effectiveness of IS in these studies could be related to inadequacy of the equipment. Most studies used the flow signal as feedback. This might enhance inspiratory flow rate rather than inspiratory volume. Volumetric IS might offer superior feedback. The use of a volumetric spirometer in our study did not show additional effects. The adaptation of the incentive spirometer with breath stacking, preventing expiration by a one-way valve to enhance the hold and achievement of high lung volumes, increased lung volume and breath holding significantly (32). However, its effectiveness was not studied on pulmonary function recovery or the prevention of pulmonary complications. Patient compliance could also affect the outcome of studies. Only the study of Hall et al. (14) reported on patient compliance with the use of the incentive spirometer and showed no significant difference in pulmonary complications. However, their conclusion to treat high-risk patients only with IS may be too optimistic because the conditions during a study period might be significantly different from routine clinical practice.

The overall low complication rate was not influenced by the addition of IS. The relatively low complication rate might be the result of the careful preoperative evaluation, including routine preoperative physiotherapy, and postoperative optimal pain control, intensive physiotherapy, nursing, and early mobilization. This was previously suggested by Nagasaki et al. (21), who considered careful preoperative care, selection of appropriate surgical procedures, and preoperative physiotherapy.

In conclusion, postoperative pulmonary complication rate was relatively low after thoracic surgery for both lung and esophageal resection. The addition of IS to physiotherapy did not further reduce pulmonary complications or hospital stay. Although we cannot rule out beneficial effects in a subgroup of high-risk patients, routine use of IS after thoracic surgery seems to be ineffective.

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