A Controlled Trial of Intermittent Positive Pressure Breathing, Incentive Spirometry, and Deep Breathing Exercises in Preventing Pulmonary Complications after Abdominal Surgery[1-4]

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SUMMARY Controversy exists regarding the routine use of aids to lung expansion in the prevention of pulmonary complications after abdominal surgery. We prospectively randomized 172 patients into 1 of 4 groups: the control group (44 patients) received no respiratory treatment, the IPPB group (45 patients) received intermittent positive pressure breathing therapy for 15 min 4 times daily, the IS group (42 patients) was treated with incentive spirometry 4 times daily, and the DBE group (41 patients) carried out deep breathing exercises under supervision for 15 min 4 times daily. Roentgenographic changes, observed 24 h after surgery, were comparable in the 4 groups (20.5 to 36.6%). Pulmonary complications were defined as the development of 3 or more of 6 new findings: cough, phlegm, dyspnea, chest pain, temperature greater than 38° C, pulse rate more than 100 beats/min. The frequency of development of pulmonary complications was 48% in the control group, 22% in the IPPB group ($p < 0.05$), 21% in the IS group ($p < 0.05$), and 22% in the DBE group ($p < 0.05$). Side effects of respiratory treatment were observed only in the IPPB group (18%; $p < 0.05$). Hospital stay in patients undergoing upper abdominal surgery was significantly shorter in the IS group (mean ± SD, 8.6 ± 3 days) than in the control group (13 ± 5 days). This difference was not observed for the other 2 treatment groups. We conclude that IPPB, IS, and DBE were equally effective in preventing pulmonary complications after abdominal surgery, although IS may be the treatment of choice in upper abdominal procedures, because there are no complications of this treatment and it appears to shorten the length of hospitalization.

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Introduction

Pulmonary complications continue to be an important cause of postoperative morbidity and mortality. They are frequent in abdominal procedures, with reported rates ranging from 25 to 80%, depending on the criteria used to define them (1–3). Because of this high incidence, many efforts have been made to prevent their occurrence. Chest physical therapy and breathing exercises have been favored in Europe, whereas treatment with mechanical aids for lung expansion has been preferred in the United States (4). Thoren (5) reported 30 yr ago in a controlled nonrandomized trial that deep breathing exercises, assisted cough, and postural drainage decreased complications after cholecystectomy from 47% in control subjects to 27% if therapy was begun after surgery and 12% if it was started before surgery. Using a multifaceted approach consisting of smoking cessation, antibiotics, bronchodilators, inhaled aerosols, and chest physical therapy, Stein and Cassara (6) showed a decrease in complications in a high-risk group from 60% (15 of 25) in the matched control group to 21% in the treatment group. These studies suggested that respiratory therapy could be beneficial in the prevention of postoperative pulmonary complications, and they paved the way for the widespread acceptance of mechanical aids to lung expansion. Intermittent positive pressure breathing (IPPB) treatments, administered for brief periods at intervals of several hours, gained popularity when they were reported to be beneficial in a single controlled, nonrandomized study (7). This finding was contested by other reports that failed to find any advantage of IPPB over no treatment (8–10). Since the early 1970s, the overall use of IPPB for this purpose has decreased (11). Incentive spirometry (IS) was reported to be more effective than no treatment in a randomized study (3) and superior to IPPB in other studies (12–14). Unfortunately, these latter studies did not include untreated control subjects, and the comparisons were made between treatments given at different time schedules. A more recent report by Jung and coworkers (15) compared IPPB, IS, and resistance breathing ("blow bottles") using similar treatment protocols. They showed that all 3 methods were associated with the same incidence of postoperative pulmonary complications. Untreated control subjects were not included, and it cannot be concluded that any method was superior to no treatment at all. Two recent editorials on the subject (16, 17), as well as 2 reports dealing with the use, magnitude, and cost of respiratory therapy in surgical patients, indicated a need for clarification of this issue (4, 11).

Our study was undertaken with 3 objectives. First, to determine if the routine use of 3 methods of respiratory therapy (IPPB, IS, and DBE) were superior to no treatment in the prevention of postoperative pulmonary complications in patients undergoing abdominal surgery. Second, to compare the 3 forms of treatment and determine if one was superior to the others. Third,

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to determine if the routine application of these treatments would result in shortening length of hospital stay, thus justifying their cost.

Methods

Patient Selection and Randomization

Two hundred patients admitted for elective surgery to a large private hospital in Maracaibo, Venezuela, participated in this study. The protocol was approved by the hospital's Human Studies Committee, and all patients gave their consent. A trained respiratory therapy technician administered a questionnaire that determined patient identification, age, sex, smoking history, history of pulmonary problems, and the presence of cough, sputum production, dyspnea, chest pain, or discomfort. The patient's weight, height, temperature, and heart rate were also recorded. Once the questionnaire was completed, the patients were randomized by the drawing of a number, to the control group or to one of the treatment groups. Then a standard preoperative posteroanterior chest roentgenogram was obtained. Forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), and forced expiratory flow from 25 to 75% of vital capacity (VC) (FEF_{25-75}) were determined using a Vitalograph wedge spirometer (Vitalograph Ltd., Buckingham, UK), according to the Snowbird Conference Standards (18). All the patients were reevaluated 24 h and 4 days after surgery with spirometry and the same questionnaire modified to inquire about any new symptom attributable to therapy. The chest roentgenogram was repeated once 24 h after the operation.

Treatment Protocol

The patients randomized to the control group received no respiratory treatment. The patients in the IPPB group were treated with intermittent positive pressure breathing at a pressure of 15 cm H_2O for 15 min. Patients were instructed in the method and respiratory excursions were observed, but volume measurements were not made. Patients in the IS group received incentive spirometry with a visual signal to indicate that the volume goal was met; a 3-s breathhold signal was used to sustain maximal inspiration. The treatments were applied a minimum of 10 breaths at volumes ranging from 100 to 1,800 ml, starting at one half of the preoperative VC until at least 70% of the VC was achieved. Those patients assigned to the DBE group were instructed to inhale increasing volumes of air, until they reached total lung capacity on the sixth breath; a breathhold period was then followed by a forced triple cough. This maneuver was carried out at least 10 times over a 15-min period.

All patients in the 3 treatment groups were instructed and begun on therapy the day before surgery and were treated 4 times daily thereafter under the supervision of the respiratory therapy technician. The duration of treatment was a maximum of 4 days; in some cases, treatment was discontinued because of complications of surgery, untoward effects from the treatments, or early patient discharge.

Criteria for the Determination of Postoperative Pulmonary Complications

The 24-h postoperative radiograph was read by one of us (BC) without information about the patient's treatment. Radiographs were read as positive when they showed atelectasis of any size, abnormal elevation of a hemidiaphragm, new pleural effusion, or the presence of a new infiltrate.

Clinically significant pulmonary complications were defined as the new occurrence of 3 or more of the following symptoms or signs: cough, sputum production, dyspnea, chest pain or discomfort, fever (temperature greater than 38° C), and tachycardia (pulse more than 100 beats/min).

Respiratory failure was defined as the development of hypoxia (Pa_{O_2} less than 50), with or without hypercapnia, necessitating mechanically assisted ventilation.

The overall management of the patients, as well as the decision to discharge the patient from the hospital, was made by each patient's attending surgeon, totally independent of this study.

Data Analysis

Each patient's record was reviewed to determine postoperative length of stay. Once the study was completed, the data were analyzed using *t* tests for nonpaired observations and discriminant function analysis (19) to determine the relative importance of the risk factors studied. Probability values of less than 0.05 were deemed significant.

Results

Of the 200 patients entering the study, 21 were excluded from analysis because of incomplete data and 7 because they had a thoracic surgical procedure. These patients were evenly distributed among the different groups, as may be seen in table 1.

TABLE 1

DISTRIBUTION OF THE PATIENTS EXCLUDED FROM ANALYSIS*

	Patient Groups			
	Control	IPPB	IS	DBE
Incomplete data	4	4	7	6
Thoracic surgery	2	1	1	3

* The patient groups were: Control, no planned pulmonary treatment; IPPB, intermittent positive pressure breathing at 15 cm H_2O peak pressure for 15 min; IS, incentive spirometry, with initial volumes ranging from 1,000 to 1,800 ml, performed a minimum of 10 times; DBE, deep breathing exercises, gradually increasing deep breaths until total lung capacity was reached, followed by breathholding and forced triple cough a minimum of 10 times. All treatments were given 4 times daily.

The characteristics of the 172 patients included in the data analysis are shown in table 2. Incisions not extending above the umbilicus were categorized as lower abdominal; those extending above the umbilicus but not entering the thorax were classified as upper abdominal. The operative report was reviewed in all cases, and there was excellent correlation between the incision site and the intraoperative manipulation. The 4 patient groups were similar when compared by age, sex, height, weight, FEV_1, smoking history, type of anesthesia (general versus spinal), type of abdominal surgery (upper versus lower), and duration of the procedure. Only 17% of the patient population had FEV_1 values less than 70% of FVC, and these patients were equally distrib-

TABLE 2

CHARACTERISTICS OF 172 PATIENTS UNDERGOING ABDOMINAL SURGERY*

	Patient Groups			
	Control	IPPB	IS	DBE
Total	44	45	42	41
Age, yr	47.1 ± 12.1	48.6 ± 15.2	48.1 ± 12.8	44 ± 12.3
Sex, M/F	19/25	14/31	13/29	13/28
Height, m	1.62 ± 0.08	1.59 ± 0.07	1.60 ± 0.09	1.59 ± 0.09
Weight, kg	69.1 ± 11.7	66.7 ± 13.1	68.5 ± 9.60	68.5 ± 20.9
FEV_1, % pred	89.9 ± 24.2	92.5 ± 22.9	91.0 ± 25.3	96.5 ± 20.9
Smoking history, > 15 pack-years	9	7	9	6
Type anesthesia, general/spinal	24/20	26/19	24/18	26/15
Type abdominal surgery, upper/lower	19/25	23/22	21/21	18/23
Duration of procedure, min	106 ± 57.4	104.9 ± 46.8	111.4 ± 64.3	99.4 ± 60.9

For definition of abbreviations for the 4 treatment groups, see table 1.

* All values are reported as mean ± 1 SD, except number of patients, sex, smoking history, type of anesthesia, and type of surgery, which are shown as absolute numbers. None of the differences among the 4 groups was statistically significant.

TABLE 3

POSTOPERATIVE PULMONARY COMPLICATIONS AND LENGTH OF STAY IN ALL PATIENTS

	Patient Groups							
	Control		IPPB		IS		DBE	
	(*n*)	(%)	(*n*)	(%)	(*n*)	(%)	(*n*)	(%)
Radiographic changes	9	20.5	13	28.9	13	31	15	36.6
Clinical complications	21	47.7	10	22.2*	9	21.4*	9	22*
Respiratory failure	4	9.17	3	6.77	0	0	2	4.9
Patients with side effects	0		8*		0		0	
Length of stay, days ± SD	9.7 ± 5.4		8 ± 5		7.5 ± 3.1		7.8 ± 3.4	

For definition of abbreviations for the 4 treatment groups, see table 1.
* $p < 0.05$.

TABLE 4

VARIABLES DETERMINED BY DISCRIMINANT FUNCTION ANALYSIS TO BE SIGNIFICANT CONTRIBUTORS TO THE DEVELOPMENT OF PULMONARY COMPLICATIONS AFTER ABDOMINAL SURGERY

Risk Factor	Standardized Canonical Discriminant Function Coefficient*
Upper abdominal surgery	0.569
No respiratory therapy treatment	0.536
Duration of surgery	0.498
Age	0.359
Weight	0.230

* The size of these coefficients (19) indicates the relative importance of the contribution of each risk factor.

uted among the 4 groups (data not shown).

The incidence of pulmonary complications by treatment group is shown in table 3. Roentgenographic complications occurred with similar frequency (21 to 36%) in the treated and untreated groups. Only 1 patient had a pleural effusion after a cholecystectomy. Clinical complications were significantly less frequent in the 3 treatment groups (21 to 22%) than in the control group (48%). Although the numbers are too small for statistical analysis, respiratory failure was most frequent in the control group, absent in patients treated with IS, and intermediate in patients treated with IPPB and DBE. Side effects of respiratory treatment, consisting of a feeling of bloating and abdominal distension, leading to discontinuation of therapy, were observed in 18% of the IPPB group. Length of stay was similar in the 4 groups.

Discriminant function analysis showed (table 4) that the factors predicting development of postoperative pulmonary complications, in order of decreasing importance, were: upper abdominal surgery, the absence of respiratory treatment, length of surgery, older age, and excess weight. Sex, height, history of smoking, FEV_1 as percent of predicted, and type of anesthesia were not found to be important predictors of such complication in our population.

We further analyzed the effects of respiratory treatment on the subset of 81 patients undergoing upper abdominal surgery (table 5). The incidence of clinical complications was significantly lower in all treatment groups than in the control group, with no differences between treatment groups. Furthermore, the administration of respiratory therapy resulted in a decrease in the length of stay in all treated groups, as compared with the control group, although statistical significance was achieved only in the patients treated with incentive spirometry.

Discussion

Lung function is invariably affected in abdominal surgery (20–22). There is a decrease in functional residual capacity (FRC), expiratory reserve volume, inspiratory and vital capacity, and expiratory flows, probably mediated by decreased diaphragmatic activity (23). Closing volume may become higher than FRC, contributing to closure of airways and atelectasis. The decrease in mucus clearance (20) and increased bacterial colonization (2) seen after surgery may lead to infection. The end result of these processes is the development of areas with ventilation-perfusion mismatch and hypoxemia, which, if severe enough, may result in respiratory failure. The incidence of these complications after abdominal surgery has been reported during the last 30 yr to vary between 25 and 80% (1–3). Several studies have determined that upper abdominal procedures (21), older age (5), obesity (21), and prolonged surgery (4) are factors that increase the risk of developing such complications. Discriminant function analysis in our patients confirmed the importance of these risk factors. We did not find a relation with the type of anesthesia. We also failed to find any relation between complications, cigarette smoking, and air-flow obstruction, as has been noted by others (5, 6, 22), probably because most of our patients were nonsmokers and relatively young, with a mean FEV_1 of 88% of predicted for all groups; only 17% of the patients had FEV_1 values of less than 70% of FVC.

General prophylactic measures, such as early ambulation, judicious use of analgesics, avoidance of restrictive abdominal bandages, and improved anesthesia technique, are believed to have a beneficial effect on the development of postoperative pulmonary complications, and they have become part of the routine management of patients undergoing surgery. The role of different forms of respiratory care in further decreasing the incidence of those complications has remained more controversial. With inadequate evidence for its effectiveness, IPPB became popular in the United States in the 1960s. Its decline since the early 1970s has been followed by an increase in the use of incentive spirometry, which today accounts for a large percentage of the total in-hospital cost of respiratory therapy (11).

In this study, we have shown that the

TABLE 5

EFFECTS OF TREATMENT IN PATIENTS UNDERGOING UPPER ABDOMINAL SURGERY

	Patient Groups			
	Control	IPPB	IS	DBE
Number of patients	19	23	21	18
Clinical complications	17 (88%)	7 (30%)*	7 (33%)*	6 (32%)*
Respiratory failure	4	3	0	2
Length of stay, days ± SD	13 ± 5	9.9 ± 6	8.6 ± 3*	9.6 ± 3.2

For definition of abbreviations for the 4 treatment groups, see table 1.
* $p < 0.05$ as compared with control.

routine use of 3 different forms of aid to lung expansion is associated with a significant decrease in the incidence of postoperative clinical pulmonary complications after abdominal surgery when compared with that in untreated control subjects. Because all 3 forms of therapy were equally effective in preventing postoperative pulmonary complications, was there any difference among them? In our IPPB group, 8 patients (18%) complained of significant abdominal distension, leading to discontinuation of therapy, a finding previously noted by Iverson and coworkers (13) in 9% of their patients receiving IPPB. This untoward effect, coupled with its higher cost, makes it the least preferred respiratory treatment in the routine management of patients undergoing abdominal surgery. Contrary to the relatively passive introduction of air provided by IPPB, IS and DBE are characterized by active recruitment of the diaphragm and other inspiratory muscles, which provides these 2 methods with a more sound physiologic rationale. From our results, we conclude that IS and DBE were similar in their prevention of clinical pulmonary complications, respiratory failure, and lack of side effects in the average patient undergoing abdominal surgery. This finding reconciles European practice in which breathing exercises are preferred and American practice in which incentive spirometry is currently the most used form of respiratory therapy treatment in surgical patients. Deep breathing exercises have the advantage of not requiring a mechanical device, making them applicable at all levels of health care, including health care in those countries with limited resources.

We found that postoperative length of stay, although shorter in all treatment groups, showed no difference when compared with the control group (table 3). However, in patients at higher risk, such as those undergoing upper abdominal surgery, there was a significantly shorter postoperative stay for those patients treated with IS, 8.6 ± 3 days (mean ± SD), versus control subjects, 13 ± 5 days; DBE and IPPB also shortened length of stay, but their variance was greater and values were not statistically significant. We conclude that, given the economic implications, further study of IS as compared with DBE seems warranted in patients at high risk of pulmonary complications. In our study, we arbitrarily elected to use 4 times daily therapy; however, in this group, an optimal treatment schedule remains to be determined.

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