Postoperative Physical Therapy after Coronary Artery Bypass Surgery

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Coronary artery bypass surgery is frequently complicated by postoperative atelectasis. Although routinely prescribed, the efficacy of any specific chest physical therapy is not well established. We studied patients at a university center undergoing elective coronary artery bypass surgery. Based upon chest X-ray criteria at extubation, patients (n = 228) were classified as demonstrating greater or lesser degrees of atelectasis. Those with a lesser degree of atelectasis were randomized to receive either early mobilization or sustained maximal inflations (SMI). Those with greater a degree of atelectasis were separately randomized to receive either SMI or single-handed percussions (SSP). We found the extent of atelectasis at extubation did not predict the risk of developing pneumonia. Hospital stays and intensive care unit stays were similar regardless of treatment. Physical therapy costs were highest in the most labor-intensive therapy group (SSP). We conclude that postoperative respiratory dysfunction is common but does not commonly cause significant morbidity or prolong hospital stay. Adding SMI to patients with minimal atelectasis at extubation does not improve clinical outcomes. Similarly, adding SSP to patients with marked atelectasis does not improve outcomes over those obtained with SMI and early ambulation. **Johnson D, Kelm C, To T, Hurst T, Naik C, Gulka I, Thomson D, East K, Osachoff J, Mayers I. Postoperative physical therapy after coronary artery bypass surgery.**

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Coronary artery bypass is presently the most common operation in North America and, following surgery, atelectasis occurs in up to 90% of patients (1). The immediate postoperative atelectasis may be due to shallow breathing (2), decreased functional residual capacity (3), or to phrenic nerve neuropraxia (1). The specific etiology may be multifactorial, and this complicates the delivery of efficacious therapy by the physical therapist, nurse, and physician caring for these patients. Traditionally, prevention and treatment of atelectasis includes early mobilization, physical therapy interventions, and a variety of respiratory maneuvers that include deep breathing, coughing, or use of incentive spirometry (4–8). These therapies have been aimed at mobilization of secretions or increasing functional residual capacity. More recently, early postoperative mobilization has been found to be as effective as chest physical therapy and respiratory maneuvers in the prevention of postoperative atelectasis or pulmonary complications (3, 9). Despite these studies, more traditional therapy is still recommended if the respiratory condition of the patient continues to deteriorate (3), but the specific type of chest therapy remains speculative (10, 11). Postural drainage and chest percussion may be poorly tolerated during the postoperative period (12, 13), and chest percussions may worsen the hypoxemia (14, 15). Therefore, although physical therapy continues to be recommended in this population, the specific interventions and their efficacy remain uncertain.

This current study was designed to evaluate whether a specific mode of therapy gave added benefits to patients after elective aortocoronary bypass surgery. We were also able to compare specific clinical outcomes and the costs of these standardized treatments. We compared three standardized regimens of postoperative therapy and evaluated their impact upon incidence of pneumonia, length of hospitalization, and hospital costs. All three treatment protocols included patient education, early mobilization, and deep breathing exercises. Patients were then randomized to receive this basic therapy alone, to receive sustained maximal inspirations (SMI) in addition to the basic therapy, or to receive modified chest percussions (SSP) in addition to SMI and basic therapy.

A secondary goal of this study was to determine whether the presence of lobar atelectasis denotes a higher risk for respiratory complications and the need for more intense physical therapy, as has been traditionally assumed (11). Therefore, we used the presence or absence of lobar atelectasis by chest X-ray to further stratify patients into those receiving a more intensive therapy that included SMI or SSP and into those receiving a less intensive therapy that included SMI or the basic treatment alone. We found that the type of therapy did not influence postoperative respiratory complications but did significantly affect postoperative costs.

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METHODS

All patients scheduled for elective coronary artery bypass graft surgery at our institution between October 1990 and April 1992 were eligible to participate. After informed consent, the following preoperative tests were obtained: postero-anterior and lateral chest X-ray, pulmonary function testing, arterial blood gases, pulse oximetry, FVC, and FEV_1. Intraoperative measurements, obtained from the anesthetic flow sheet, included aortic cross-clamp time and total cardiopulmonary bypass time.

All patients were evaluated preoperatively by a staff physical therapist and were given uniform instructions concerning mobilization and breathing exercises. If extubated within 48 h after surgery, patients were stratified into one of two groups based upon a chest X-ray obtained on the morning of extubation (Figure 1). Chest X-rays were interpreted as having minimal atelectasis (no atelectasis or one segment involvement) or as having marked atelectasis (lobar atelectasis or two separate areas of segmental atelectasis). Patients having minimal atelectasis were randomized to receive early mobilization (Group I) or to receive early mobilization with SMI (Group II). Those with marked atelectasis were randomized to receive early mobilization with SMI (Group III) or to early mobilization, SMI, and single-handed percussion (SSP) (Group IV). Early mobilization consisted of graded increases in activity beginning on the first postoperative day and increasing over a 5-d period until independent unassisted ambulation was achieved. It also included patient education and instruction to take five deep breaths hourly. The SMI maneuver consisted of a series of stacked inhalations from functional residual capacity to total lung capacity (TLC) with a 5-s breath-hold at TLC for a total of five repetitions. These were performed hourly, while awake, with the patient supine, or upright if tolerated, and then in a right lateral decubitus position. The SSP maneuver consisted of the administration of cupped-hand percussions to the chest wall, applied at a rate of one to two per second and given at TLC during a complete SMI maneuver. Three sessions of SSP were given daily. During all treatment sessions, the incidence of complications was recorded. Each patient maintained a log of their frequency of deep breathing and SMI maneuvers. Patient perception of pain was also assessed using a visual analog score where: 0 = no pain; 1–2 = mild pain; 4–6 = moderate to severe pain; and 10 = excruciating pain. Logs were reviewed daily, and patients received appropriate verbal feedback. Finally, the time each physical therapist spent with each patient was recorded.

All chest X-rays were graded by a radiologist blinded to treatment using a scoring scale (1): 0 = no atelectasis; 1 = plate atelectasis; 2 = subsegmental atelectasis; 3 = segmental atelectasis; 4 = lobar atelectasis. The right and left lungs were scored independently and then summed to yield a total chest X-ray atelectasis score.

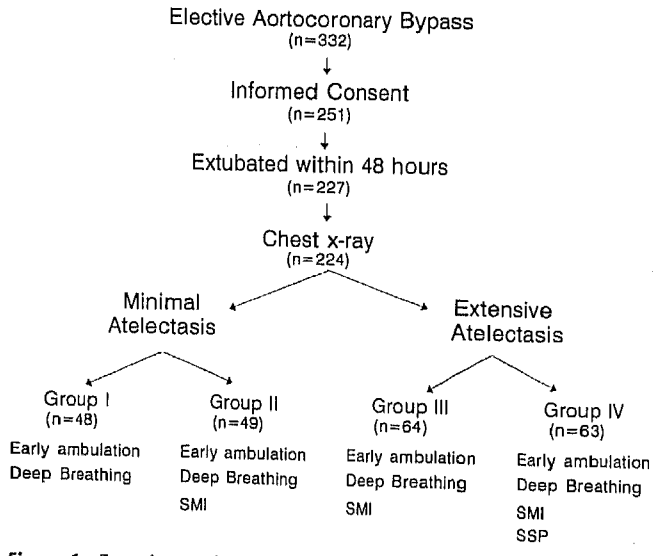

Figure 1. Experimental protocol. Based upon the chest X-ray obtained the morning of extubation, patients were allocated to minimal or extensive atelectasis groups and were then randomized to physiotherapy. Note that all patients received a common therapy of early mobilization with deep breathing exercises.

We defined pneumonia by the presence of three of the four following criteria: elevation of white blood cell count to greater than 10^9/L, elevation of temperature to greater than 38.5° C orally, presence of a known respiratory pathogen in a sputum sample, and presence of new infiltrate or air bronchogram compared with a previous chest X-ray. For patients receiving oral acetaminophen, an elevated temperature was not required, and only two of the remaining three criteria were then required. A chest X-ray was routinely ordered on days 1, 2, 3, and 5 of follow-up, but if during daily examination by the research nurse or staff physical therapist, the diagnosis of pneumonia was clinically suspected, then a sputum culture and a chest X-ray were ordered.

We prospectively determined the personnel costs associated with each group. Physical therapy costs were calculated multiplying the time of active clinical physical therapy delivery to each patient times the hourly costs of wages and benefits of the physical therapists. An additional 50% was added to these costs in order to account for other activities not directly related to patient care (preoperative assessment, teaching, and charting). Nursing costs for each patient over the 5-d treatment protocol were estimated using a medicus score. Briefly, a medicus score estimates nursing time for a given patient based upon the patient's cognitive and ambulatory capabilities. Nurse staffing needs can then be based upon the total daily medicus score for each hospital ward. We obtained the ward medicus scores, calculated twice daily, as well as the total ward nursing wages during our study period. We then derived a local institutional nursing cost per medicus score point per patient. We calculated the following set of dollar values per score point: score 1 = \$10.45 per patient per day; score 2 = \$55.73 per patient per day; score 3 = \$108.62 per patient per day; score 4 = \$135.77 per patient per day.

Statistics

Student's *t* test with a Bonferroni correction for multiple comparisons was used to determine the significance of differences in proportions between two groups and also the differences between two means. A two-sided α level of 0.05 was used as the cutoff for statistical significance. Odds ratios and their corresponding 95% confidence intervals (CI) were computed by the standard Mantel Haenszel method (16).

RESULTS

During the period of October 1990 to April 1992, a total of 332 patients had aortocoronary artery bypass surgery at our institution. Of these, 251 patients met eligibility criteria and gave informed consent for entry into the study. Of the 251 patients entering the study, one died intraoperatively (0.4%) and 23 (9%) were not randomized because extubation was delayed to greater than 48 h postoperatively. Of the 23 patients not randomized, three eventually died, four sustained severe neurologic complications, five had delayed emergence from anesthetic, three withdrew consent, and eight were hemodynamically unstable. Four of the 23 patients eventually developed pneumonia, but none of the patients was not randomized because of already existing respiratory failure.

Of the total study group, 228 patients (91%) were randomized, but three patients (1%) withdrew consent and five patients (2%) sustained cardiac complications. Partial data on four of the five patients with cardiac complications were still obtained. Four patients received treatment in excess of their group randomization because of perceived respiratory difficulty as assessed by the study nurse and physical therapist. One patient randomized to Group I, one randomized to Group II, and two randomized to Group III were given SMI and SSP (i.e., received Group IV therapy). Data from these patients was included in analysis until the break in protocol, and the break in protocol was considered to be a complication of their treatment. All four of these patients met the clinical criteria for the diagnosis of pneumonia (see below) at the time of their change in treatment. In this manner, we analyzed data from 224 patients (90%), with 216 patients completing the entire 5-d protocol. The final randomization consisted of 48 patients in Group I, 49 in Group II, 64 in Group III, and 63 in Group IV.

TABLE 1

PREOPERATIVE DEMOGRAPHICS AND ADMISSION DATA

	Group I	Group II	Group III	Group IV
Age, yr	60 ± 10	64 ± 11	66 ± 8	64 ± 11
Sex				
Male	39	40	52	53
Female	9	9	12	10
Body mass index, kg/m^2	30 ± 5	29 ± 4	28 ± 4	28 ± 4
Stroke, number of patients	1	1	4	1
Diabetes, number of patients	10	5	15	7
P_{O_2}, mm Hg	76 ± 9	78 ± 15	78 ± 9	81 ± 13
Left ventricular ejection fraction, %	59 ± 14	58 ± 12	56 ± 15	53 ± 14
Saphenous vein grafts per patient	3.2 ± 1.0	3.4 ± 1.1	3.3 ± 1.0	3.5 ± 0.9
Internal mammary grafts, number of patients	34	37	54	57
Extracorporeal oxygenation time, min	98 ± 25	100 ± 29	96 ± 25	106 ± 28
Cross clamp time, min	59 ± 21	60 ± 21	57 ± 17	63 ± 16
Pleural space entered, number of patients	30	27	34	45

Outcomes

Table 1 illustrates selected demographic data for all four groups. The groups were similar in terms of all preoperative, intraoperative, and immediate postoperative parameters that were assessed. Preoperative laboratory measurements, lung functions, chest X-ray scores, and arterial oxygenation were also similar between groups (Table 2). All our measured parameters on admission to the intensive care unit (ICU) were similar between groups. These included cardiac index (range, 2.2 to 2.4 L/min/m^2), pulmonary artery occlusion pressure (range, 13 to 15 mm Hg), fluid balance (range, +3.7 to +4.5 L), alveolar to arterial oxygen gradient (range, 155 to 172 mm Hg), duration of intubation (range, 23 to 26 h), and presence of viscous tracheal secretions (range, 17 to 30 patients).

As determined by study design, the chest X-ray atelectasis scores after extubation were higher in Group III (4.9 ± 1.1) and Group IV (4.8 ± 1.2) compared with Group I (3.2 ± 1.3) and Group II (3.7 ± 1.2). Lobar collapse was present in 32 (50%) and 35 (56%) patients in Groups III and IV, respectively, and absent in Groups I and II at time of extubation. The prevalence of other chest X-ray abnormalities was similar between all four groups. These abnormalities included cardiomegaly (range, 3 to 9 patients), pulmonary edema (range, 0 to 3 patients), massive gastric distention (range, 7 to 10 patients), pneumothorax (range, 1 to 4 patients), and pleural effusion (range, 44 to 64 patients).

Table 2 also illustrates values of postextubation respiratory function. All measured values showed marked deterioration comparing admission to hospital discharge values for each group ($p < 0.0001$); however, hospital discharge values of lung volumes and spirometry were similar between groups ($p > 0.05$). Chest X-ray atelectasis scores did not significantly improve from extubation to hospital discharge values. The chest X-ray obtained at hospital discharge showed lobar collapse in 6% of Group I, 2% of Group II, 25% of Group III, and 17% of Group IV. The only postoperative variable showing a significant difference between groups was the total 5-d weight gain. Over the 5 d after randomization, weight gain from preoperative values was greater in Group III (4.9 ± 3.4 kg) and Group IV (6.2 ± 4.6 kg) compared with Group I (3.4 ± 2.6 kg) and Group II (3.4 ± 3.1 kg). The postoperative use of diuretics (range, 31 to 51 patients) or bronchodilators (range, 8 to 10 patients) was similar between groups.

Table 3 illustrates the prospectively selected outcome variables of this study. We prospectively selected total length of hospital stay and total length of ICU stay as two quantifiable outcomes. We found that both the length of stay in the ICU and the total length of stay in hospital were greater in Groups III and IV compared with Groups I and II. However, using an 8-d stay as the fiftieth percentile for length of hospital stay of the four groups combined, the odds ratios for length of stay in hospital in Groups III and IV were 2.13 (95% CI, 0.90 to 5.03) and 1.52 (95% CI, 0.63 to 3.69), which were not statistically different compared with Group I. The odds ratio for length of stay in the ICU when total hospital stay was greater than 8 d was significantly different for Group III (5.13; 95% CI, 1.49 to 16.79) and Group IV (4.29; 95% CI, 1.24 to 14.78) compared with Group I. The increased length of stay in the ICU was not dependent upon the subsequent development of pneumonia, as after adjusting for pneumonia, the odds ratio was still statistically different in Group III (5.13; 95% CI, 1.47 to 17.20) and Group IV (4.31; 95% CI, 1.23 to 15.16) compared with Group I. However, when long-stay patients (length of hospital stay greater than 15 d) were excluded in Group III (n = 3) and Group IV (n = 4), the odds ratios were similar for length of hospital stay and ICU stay for all groups. None of the seven long-stay patients remained hospitalized primarily because of respiratory complications.

There were not any differences in the diagnosis of pneumonia between any of the four groups by the odds ratio. There were also no differences when the criteria required to make the diagnosis of pneumonia were individually compared between groups. As illustrated in Table 3, the length of total hospital stay or ICU stay was not increased by the diagnosis of pneumonia.

TABLE 2

CHANGE IN RESPIRATORY FUNCTION FROM ADMISSION TO DISCHARGE*

	Group I		Group II		Group III		Group IV	
	Admission	Discharge	Admission	Discharge	Admission	Discharge	Admission	Discharge
VC, L	4.0 ± 0.9	2.7 ± 0.7	3.9 ± 0.8	2.8 ± 0.5	3.9 ± 0.9	2.8 ± 0.6	4.2 ± 0.8	3.0 ± 0.6
FRC, L	3.9 ± 0.8	2.9 ± 0.8	3.7 ± 0.9	3.4 ± 0.8	4.2 ± 1.0	3.3 ± 0.8	4.3 ± 1.0	3.8 ± 1.0
FEV_1, L	2.7 ± 0.9	1.8 ± 0.5	2.5 ± 0.8	1.7 ± 0.5	2.7 ± 0.7	1.8 ± 0.5	2.9 ± 0.8	2.0 ± 0.6
D_{LCO}, ml/min/mm Hg	26 ± 5	15 ± 3.5	23 ± 4	15 ± 2.9	24 ± 6	15 ± 3.3	24 ± 6	15 ± 3.9
Hand grip, mm Hg	38 ± 14	37 ± 14	38 ± 12	36 ± 13	36 ± 10	36 ± 10	38 ± 12	37 ± 12
Maximum expiratory pressure, cm H_2O	92 ± 33	75 ± 24	92 ± 30	70 ± 23	87 ± 28	71 ± 24	91 ± 28	69 ± 22
Negative inspiratory pressure, cm H_2O	76 ± 29	57 ± 22	73 ± 32	54 ± 30	79 ± 30	60 ± 31	77 ± 36	58 ± 31
X-ray score	0.1 ± 0.4	3.6 ± 1.7	0.2 ± 0.5	3.1 ± 1.7	0.4 ± 0.8	4.5† ± 1.4	0.4 ± 1.0	4.1† ± 1.8

* Note that all admission values were significantly different from discharge values ($p < 0.0001$).
† $p < 0.01$ comparing Groups I and II with Groups III and IV.

TABLE 3

MORBIDITY AFTER AORTOCORONARY BYPASS SURGERY

	Group I	Group II	Group III	Group IV
Intensive care unit stay, days	2.0 ± 0.5	2.1 ± 0.5	2.3 ± 0.8*	2.3 ± 0.6*
Hospital stay, days	8 ± 1.5	8 ± 1.6	9 ± 2.7*	10 ± 8.5*
Hospital stay of patients without pneumonia, days	8 ± 1.6	8 ± 1.6	9 ± 2.9	10 ± 8
Hospital stay of patients with pneumonia, days	7 ± 0.5	8 ± 0.8	8 ± 1.0	12 ± 11
Number of long-stay patients > 15 d	0	0	3*	4*
Adjusted hospital stay with pneumonia (days) excluding stay > 15 d	7 ± 0.5	8 ± 0.8	8 ± 1.0	8 ± 1.4
Adjusted hospital stay without pneumonia (days) excluding stay > 15 d	8 ± 1.6	8 ± 1.6	8 ± 1.4	8 ± 1.1
Pneumonia criteria (number of patients)				
Temperature	4	4	9	9
X-ray	14	11	22	19
Sputum pathogen	1	4	3	2
White blood cell count > 10^9/L	15	12	22	23
Meets criteria for pneumonia	8	10	14	13

* Significant difference ($p < 0.05$) between Groups I and II compared with Groups III and IV.

We estimated patient compliance with the prescribed physical therapy regimen by a self-reported log. We found that the total number of deep breathing exercises for the 5-d treatment (range, 45 to 49 per patient) and daily average (range, 9 to 10 per patient) were similar between all groups. Use of analgesic (650 mg acetaminophen with 60 mg codeine) was similar between groups. As well, visual analog pain scores were similar between groups assessed either as a daily measurement (range, 3.5 to 3.7) or as a combined 5-d score. Therefore, we believe that pain was not a confounding variable altering compliance with any treatment regimen.

Personnel Costs

Table 4 illustrates time and money spent upon patients in each study group. As expected by study protocol, the total time a physical therapist spent with a patient was similar for Groups I and II. Although Groups II and III were prescribed identical therapy (early mobilization with SMI), we found that physical therapists spent significantly more time with Group III patients compared with Group II patients. The increased time included routine pulse oximetry monitoring for Group III patients, which was routinely performed for Group II patients. Physical therapist with Group IV patients was twofold greater than for any o group. It was expected by study design that these patients recei the most intensive time would in fact have the greatest perso costs. We found that physical therapy times and costs were grea for Group IV patients compared with Groups I, II, and patients. We found that both the daily and total medicus sc were similar between Groups I and II and were similar betw Groups III and IV. However, there was a significant increas medicus scores comparing Groups III and IV with Groups I an

DISCUSSION

The primary goal of this study was to evaluate whether any modality of standard chest physical therapy is effective at re ing the respiratory morbidity that follows aortocoronary by surgery. Previous studies have not found any single techni to be better at minimizing postoperative atelectasis or pneu nia (9, 12, 13, 17–20). There is indirect evidence to suggest periodic maximal lung inflations may be of benefit since may increase surfactant production, which in turn may impr lung compliance and systemic oxygenation (21, 22). As well, proved regional inflation, may, through alveolar interdepende help to re-expand atelectatic units (23).

Mechanical aids such as the incentive spirometer are c monly used postoperatively, but they (12) are no more effec than early mobilization alone (3). Both SMI and incentive spir etry can be performed independently and repetitively by the tient. However, SMI does not require any additional mater and may therefore reduce the costs of providing therapy (Therefore, we elected to only test the efficacy of specific brea ing maneuvers. Along with SMI, we also evaluated SSP for tr ment of established atelectasis. The use of SSP in this set is widespread, but its effectiveness in altering clinical outc has not been established (11). Finally, the presence of lobar lapse has been traditionally associated with increased resp tory morbidity, and it has been assumed that more intensive p ical therapy is indicated. We therefore evaluated whether lo collapse after aortocoronary bypass was important in the de opment of postoperative morbidity. We followed the clin course of patients with a common physical therapy regimen had lobar collapse (Group III) and compared them with ide cally treated patients without lobar collapse (Group II).

Our study found similar lung function changes, as have pr ous smaller studies (22–30). Static lung volumes (vital capac functional residual capacity) showed marked decreases that sisted to the time of discharge. We also found evidence of creased obstruction to airflow with a decline in the ratio of FE to FVC from admission to discharge. Finally, we found sign cant decline in the single-breath D_{LCO} (25) at time of discha from hospital. Unlike a prior study (31), we did not find any these changes to be associated with specific morbidity. The ge

TABLE 4

POSTOPERATIVE COSTS FOR DELIVERY OF PHYSIOTHERAPY*

	Group I	Group II	Group III	Group IV
Total medicus score	13.6 ± 1.3	13.6 ± 1.4	14.1 ± 1.2†	14.1 ± 1.1†
Excess nursing costs per patient	$462.18 ± 61.20	$461.85 ± 64.88	$486.07 ± 5.30†	$485.25 ± 51.95†
Physiotherapy time, min	94.7 ± 31.8	105.6 ± 31.5	121.3 ± 40.1†	266.3 ± 46.1‡
Physiotherapy costs per patient	$79.00	$88.00	$100.00†	$222.00‡

* Note that all dollar values are estimates and are given in Canadian funds.
† Significant difference between Groups III and IV compared with Groups I and II.
‡ Significant difference ($p < 0.05$) comparing Group IV with all other groups.

alized decrease in static lung volumes (24–30) has also been associated with a decrease in respiratory muscle strength (25). We also found a 30% decrease in respiratory muscle pressure generation as assessed by the peak inspiratory and expiratory pressures. We found only a slight decline in skeletal muscle strength (5%), suggesting that the decline in mouth pressures was not due to a generalized myopathy but rather reflected respiratory muscle impairment (24). Although others have suggested that the respiratory impairment after aortocoronary bypass surgery is due to postoperative pain (1, 29), we found that our patients rated their pain intensity as only mild to moderate. Therefore, after aortocoronary bypass, there is usually a mixed obstructive and restrictive defect on lung function testing; however, we did not find specific clinical sequellae associated with these laboratory abnormalities.

Our data do not support the suggestion that atelectasis is associated with major respiratory complications after aortocoronary bypass. Segmental atelectasis was common in all groups and persisted to the time of discharge home. The reported incidence of pneumonia after aortocoronary artery byass has ranged between 3 and 16% (9, 12, 17, 32) and was 12% in this study. The clinical diagnosis of pneumonia may not accurately reflect the true incidence of pneumonia in a critical care setting (33–35), but we did not find any patients who progressed to develop postoperative respiratory failure. As well, none of the patients required repeat admission to the ICU because of respiratory complications. Finally, the diagnosis of pneumonia did not adversely influence the length of hospital stay. Thus, although significant decreases in static lung volumes may be found and marked atelectasis is routinely noted on chest X-ray, these abnormalities do not routinely translate in a worsened hospital course.

We did not show that any one of the physical therapy techniques produced a clinically superior effect after aortocoronary bypass surgery. Because we did not believe that it was ethical to withhold chest physical therapy from any patients, all groups received active treatment. Even the group receiving the basic treatment (education, mobilization, and deep breathing) likely received more therapist time than would be usually allocated to these activities had they not been part of a study. Stiller and colleagues have recently evaluated the role of routine chest physical therapy after coronary artery byass surgery (36). They studied 120 patients and included a control group that did not receive preoperative or postoperative chest physical therapy but did include early mobilization as part of their routine therapy. They also found no difference in pulmonary complications between their treatment groups and their control group.

We did not address the effects of treatment upon the patients who could not be extubated within 48 h. However, we found that the great majority of patients are extubated within the first 48 h after surgery and they are unlikely to develop respiratory complications that seriously influence their hospital course. Compliance with basic therapy was high and was similar in all groups as assessed by the self-recorded patient log. Physical therapy stressing early mobilization and deep breathing was as effective as SMI, with deterioration in respiratory status being infrequent. Only four of 19 patients with a clinical diagnosis of pneumonia in Groups I, II, and III were thought to be so symptomatic that a more intensive physical therapy treatment was instituted. This change in therapy was based upon the expectation that SSP is more effective at treating established pneumonia. We did, however, find on comparing SMI with SSP (Group III with Group IV, respectively) that SSP did not decrease the incidence of pneumonia or shorten hospital stay. SSP was associated with an increased incidence of minor complications, although at a decreased incidence compared with previous report (15). We found that oxyhemoglobin saturation fell below 90% in seven of 295 treatments. As well, tachycardia was induced in 12 of 295 treatments. None of these episodes was associated with significant alterations in blood pressure. Thus, no one therapy appeared to shorten hospital stay or reduce the incidence of pneumonia.

We did find, unexpectedly, that the diagnosis of pneumonia, using conventional clinical criteria, did not predict an increased duration of hospitalization. We also found that although patients having increased atelectasis on extubation (Groups III and IV) were not at increased risk for the development of pneumonia, all long-stay patients (greater than 15 d) came from these two groups. The duration of stay in the ICU, independent of development of pneumonia, was also prolonged in these two groups. The other distinguishing feature of these two groups was an increased postoperative weight gain, indicative of increased fluid retention. We believe that these features are explained by these patients developing a more severe generalized injury secondary to bypass, with increased fluid retention and increased atelectasis merely reflecting the severity of the injury. Thus, the observation of increased postoperative atelectasis may be predictive of a more complicated hospital course.

The use of chest physical therapy has become part of routine postoperative care (3, 13), but despite its common practice, the benefits of labor-intensive methods of therapy (chest percussion or vibration) compared with less labor-intensive methods of therapy (early mobilization and deep breathing) are not well documented (13). In this study, all patients received similar basic therapy (patient education, deep breathing exercises, and early ambulation). One subset of patients (Group I) received no further therapy. The remaining patients all received SMI in addition, and one further subset also received SSP in addition to SMI and basic therapy (Group IV). Thus, we established a graded intensity of treatment from least intensive (Group I) to most intensive (Group IV). We did not test if the least intense treatment (early ambulation and deep breathing) would also yield the same clinical outcome as SMI in patients with marked atelectasis at the time of extubation. Recent findings in a similar patient population would suggest that early ambulation could be the initial therapy for all patients after coronary artery bypass surgery (36). Based upon our findings, we also recommend that physical therapy after aortocoronary bypass surgery stress patient education, deep breathing, and early ambulation. Physical therapy time spent with each patient need not exceed 90 to 100 min with an emphasis on patient instruction. Only four of 160 patients (2.2%) had more intensive physical therapy than initially prescribed and, of these, in only two was their hospital stay longer than average. Thus, labor-intensive physical therapy need not be routinely prescribed in the absence of clinical signs of respiratory compromise. Although this study was not designed to assess the effectiveness of SSP, this study did demonstrate that its application can be delayed until clinically warranted. The cost incurred with more labor-intensive physical therapy regimens is more than double that of the less intensive regimen. Assuming that SSP is beneficial, this regimen need not be prescribed in more than 3% of elective patients after aortocoronary artery bypass surgery. Thus, in summary, we have demonstrated that SMI prescribed to patients with minimal atelectasis at the time of extubation does not improve clinical outcome over that obtained by deep breathing and early ambulation alone. Similarly, routinely prescribing SSP to patients with marked atelectasis noted at the time of extubation does not improve clinical outcome over that achieved by SMI and early ambulation. Using these minimal treatments routinely would then result in marked savings and allow reallocation of scarce physical therapy resources to more beneficial areas.

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