

Acute lobar atelectasis: A comparison of five physiotherapy regimens

Kathy Stiller, Sue Jenkins, Ruth Grant, Tim Geake, James Taylor and Bob Hall

Thirty-five patients with acute lobar atelectasis were allocated to one of five treatment groups (seven patients per group). Intubated patients received manual hyperinflation and suction with or without the addition of postural drainage or modified postural drainage and chest wall vibrations. For the non-intubated patients, deep breathing, coughing and huffing replaced the techniques of manual hyperinflation and suction. Frequency of treatment ranged from hourly for 6 h for four groups, to one treatment only for the fifth group. The results suggest that modified postural drainage is an effective additional component to manual hyperinflation and suction performed hourly for 6 h. The addition of chest wall vibrations to this treatment regimen did not further enhance the response to treatment, nor did the use of traditional postural drainage positions. There was evidence that hourly treatment for 6 h using modified postural drainage, manual hyperinflation and suction was more effective than one treatment only.

INTRODUCTION

Acute lobar atelectasis (ALA) is most often encountered in critically ill patients and is thought to result from airway obstruction, decreased regional ventilation and/or decreased pulmonary compliance. Because of the adverse effects on recovery of the potential complications of persistent ALA, which are said to include hy-

poxaemia, bronchopulmonary infection and pulmonary fibrosis, an aggressive approach towards the treatment of ALA has been advocated (Marini, Pierson and Hudson, 1979). Marini et al (1979) showed that initial fiberoptic bronchoscopy did not add to the effectiveness of physiotherapy (postural drainage, percussion, hyperinflation and suction) in the treatment of ALA. Johnson, Marini, Pierson and Hudson (1987), in a preliminary investigation into which components of physiotherapy were effective in the treatment of ALA, reported that postural drainage and percussion did not add to the effectiveness of deep breathing and coughing. Our initial study (Stiller et al, 1990) found that, at least initially in the course of ALA, modified postural drainage and vibrations performed hourly for 6 h significantly increased the effectiveness of a treatment of manual hyperinflation

K. Stiller, Department of Physiotherapy, **T. Geake**, **J. Taylor**, Department of Radiology, Royal Adelaide Hospital, North Terrace, Adelaide, SA 5000, Australia

S. Jenkins, School of Physiotherapy, Curtin University of Technology, Perth, WA 6008, Australia

R. Grant, Faculty of Health and Biomedical Sciences, **B. Hall**, School of Mathematics, University of South Australia, Adelaide, SA 5000, Australia

(Reprint requests to KS)

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and suction. The aim of the present study was to investigate further which components of physiotherapy are effective in the treatment of ALA. The questions addressed were as follows: (1) Could vibrations be omitted from a treatment of modified postural drainage, manual hyperinflation and suction without loss of effect? (2) Would traditional postural drainage enhance the response to treatment? (3) Would one treatment be as effective as hourly treatment for 6 h?

To allow a comparison of the results, selected methodology and data from the study by Stiller et al (1990) were replicated in this paper.

MATERIALS AND METHODS

Patients

All patients admitted with, or who developed, ALA while in the intensive care unit or high dependency unit of the Royal Adelaide Hospital, were considered for inclusion in the study. The ALA was diagnosed by two radiologists and defined as 'volume loss conforming to a characteristic pattern (radiographic density, fissure displacement, mediastinal shift, diaphragmatic elevation, and compensatory hyperinflation)' (Marini et al, 1979). Patients were excluded if they were unable to lie on their side with the bed flat, or if ALA was due to obstruction by a tumour or incorrect placement of an endotracheal tube. As ALA involving the left lower lobe after coronary artery surgery is believed to have an aetiology and course which is unique to that condition (Benjamin et al, 1982; Large et al, 1985; Markland et al, 1985), patients with ALA of the left lower lobe after coronary artery surgery were also excluded. As the treatment for non-intubated patients required their cooperation, non-intubated patients with a decreased conscious state were excluded. The study was approved by the Human Ethics Committee of the Royal Adelaide Hospital.

Groups

In the initial study (Stiller et al, 1990), patients were alternately allocated to one of two groups

(Groups 1 and 2). In this follow-up study, patients were randomly allocated to one of three groups (Group 3, 4 or 5).

- *Group 1*: treatment consisted of manual hyperinflation and suction performed hourly for 6 h.
- *Group 2*: patients received modified postural drainage and chest wall vibrations in addition to manual hyperinflation and suction performed hourly for 6 h.
- *Group 3*: treatment comprised modified postural drainage (but not vibrations) in addition to manual hyperinflation and suction performed hourly for 6 h.
- *Group 4*: patients received postural drainage, manual hyperinflation and suction performed hourly for 6 h.
- *Group 5*: patients received the same treatment as for Group 3 patients (modified postural drainage, manual hyperinflation and suction) but received one treatment only.

For non-intubated patients, deep breathing, coughing and huffing replaced manual hyperinflation and suction.

Techniques

Positioning

Group 1 patients did not have any specific positioning employed as part of their treatment. They were turned every 2 h by the nursing staff from side to side or supine with the bedhead elevated approximately 30°. That is, the position in which Group 1 patients were nursed was not dependent on which area of the lung was involved. Patients in Groups 2, 3 and 5 were positioned in side-lying with the bed flat and the involved lung uppermost (modified postural drainage). Group 4 patients were placed in traditional postural drainage positions, many of which, depending on the area of the lung affected, involved patients being tilted head down (Webber, 1988). These positions were maintained for at least 15 min prior to the application of the other techniques.

Other techniques

While in the appropriate position, manual vibrations to the chest wall overlying the involved area were given during expiration to patients in Group 2 for 5 min prior to suction. For intubated patients, manual hyperinflations were given in groups of 6–8 inflations using a two-litre anaesthetic bag (inspired fraction of oxygen = 1.0). Each hyperinflation was held at full inflation for up to 5 sec. Cycles of hyperinflation were given for approximately 2 min prior to and between each suctioning procedure. Non-intubated patients were verbally encouraged to breathe to their maximal volume (in a similar pattern to the manual hyperinflation procedure) prior to and between each coughing and huffing procedure. These deep breaths, similar to sustained maximal inspirations, commenced from resting end expiratory volume and were interspersed with relaxed breathing. Suctioning (intubated patients) or coughing and huffing (non-intubated patients) was continued until all secretions were cleared at any one time. Nasotracheal suction was performed on the non-intubated patients whose cough was ineffective.

One physiotherapist (K.S.) supervised the positioning, postural drainage, manual hyperinflation, deep breathing and coughing and performed the vibrations and suction for all patients.

Following the intensive 6 h treatment period, or single treatment for patients in Group 5, management reverted to that routinely used, namely 2 hourly suctioning after approximately 20 min of flat side-lying for intubated patients and deep breathing and coughing exercises every 2 h for non-intubated patients.

Measurements

General data such as the age, sex and primary diagnosis of patients were noted. Portable chest X-rays were obtained following the first treatment intervention and after the 6 h intensive treatment period. Group 5 patients also had a chest X-ray 6 h after their single treatment. In addition, whenever possible, follow-up chest X-rays were taken 24 and 48 h after the initial diagnostic X-ray. Chest X-ray evaluation was performed by

two radiologists who were blind to the patient's identity, general condition and treatment group using the system described by Marini et al (1979). The radiologists independently compared the initial diagnostic chest X-ray with signs of ALA to a pre- or post-study film without signs of atelectasis, and thus assessed the amount of volume loss on the initial film. The amount of collapse in all subsequent films was estimated and expressed, to the nearest 10%, as a percentage of the original volume loss. This represents the mean percentage resolution of ALA. When precise agreement between the radiologists was not obtained, the average of the two percentages was recorded.

Intra- and inter-examiner reliability were determined by the two radiologists independently estimating the percentage collapse for a series of 35 chest X-rays from seven patients with evidence of complete or resolving ALA and repeating this procedure approximately 2 weeks later with the same films. Using intra-class correlation (Shrout and Fleiss, 1979; Haas, 1991a), the correlation coefficients for intra-examiner reliability were 0.89 for radiologist 1 and 0.87 for radiologist 2. The correlation coefficient for the inter-examiner reliability was 0.92. These values represent good intra- and inter-examiner reliability (Haas, 1991b).

Other data collected included intubation/ventilation status, the volume of sputum cleared during treatment (to the nearest 5 ml), results of analysis of arterial blood gas (ABG) samples together with the inspired fraction of oxygen (FiO_2), rectal temperature and white cell count. These measurements were made by staff not directly involved in the study.

The results obtained for chest X-ray evaluation and other measurements and observations after one treatment and at the end of 6 h were most likely to reflect the effect of the treatment groups on the resolution of ALA, as other variables associated with the changeable general medical condition of critically ill patients may have influenced the results obtained at 24 and 48 h. Nevertheless, we believed it was important to ascertain whether any improvements seen were maintained with the routine management received after the intensive 6 h treatment period (or single treatment for Group 5 patients).

Statistical analyses

Statistical analyses were completed using the JMP statistical software package on a Macintosh Powerbook 170 computer. All analyses were made using analysis of variance (ANOVA) techniques. Probability values of less than 0.05 were considered significant. Where the usual assumptions underlying standard ANOVA calculations did not hold true for measurements (e.g. normal distribution for percentage resolution of ALA), the probability values quoted are approximate. However, when non-parametric techniques were applied, the *P*-values obtained were within ± 0.03 of the values obtained from analysis of the raw data. Standard errors (SE) have been cited which measure the standard deviation of the means of each group. They are based on pooled estimates of standard deviations from the ANOVA tables.

RESULTS

In total, 33 patients with acute lobar atelectasis were studied in the initial and the present study. Two patients were studied twice, each occasion separated from the other by a period of days. Thus in total there were 35 episodes of ALA, 7 per group. The first 14 patients, who were allocated to Groups 1 and 2, were studied between 13

November 1987 and 14 June 1989, and the remaining 21 patients, who formed Groups 3, 4 and 5, were recruited into the study between 10 October 1989 and 18 June 1993. In only two patients were the initial diagnostic chest X-rays taken for investigation of clinical deterioration (hypoxaemia, fever and shortness of breath). In the other patients, ALA was detected on a routine daily chest X-ray, although there was associated clinical deterioration in 18 of these patients. In all patients, ALA was deemed to be of recent onset, because it had not been present on a chest X-ray taken within the previous 48 h. Over the course of the study, a total of 31 patients were excluded from participation. Twelve patients were excluded as positioning in flat side-lying was contraindicated due to spinal injury or head injury with high intracranial pressure. A further 11 patients were excluded as ALA was secondary to incorrect placement of an endotracheal tube, 4 patients had ALA of the left lower lobe after coronary artery surgery and 4 non-intubated patients had a decreased level of consciousness.

Descriptive data for the patients included in the study, according to their allocated group, are given in Table 1. The 35 patients (18 males, 17 females) had a mean age of 43.1 years (range 17–80 years). There was no significant difference between the groups in their mean age (*F*-test, *P*=0.21), although the patients in Group 1 were younger than those in the other groups (Table

Table 1
Descriptive information by group

	Group 1	Group 2	Group 3	Group 4	Group 5
Sex (F/M) (<i>n</i>)	2/5	1/6	4/3	6/1	4/3
Age (years) ^a	28.4 ± 7.5	45.3 ± 7.5	50.6 ± 7.5	40.3 ± 7.5	51.1 ± 7.5
Primary diagnosis (<i>n</i>)					
neurological condition	5	3	4	2	4
post-operative	1	1	2	3	2
other	1	3	1	2	1
Intubation status (I/NI) (<i>n</i>) ^b	6/1	5/2	7/0	5/2	7/0
Ventilation status (IPPV/SV) (<i>n</i>) ^c	4/3	5/2	5/2	4/3	6/1
Location of ALA (<i>n</i>)					
left lung	1	0	0	1	0
right lung	0	1	0	0	0
left lower lobe	5	2	5	2	4
right lower lobe	1	3	2	0	3
right upper lobe	0	1	0	4	0

^aMean ± standard error. ^bI, intubated; NI, not intubated. ^cIPPV, intermittent positive pressure ventilation; SV, spontaneously ventilating.

1). The patients had a variety of primary diagnoses, with neurological ($n=18$) and post-operative conditions ($n=9$) the most common. The ALA involved the entire lung in 3 cases (2 left, 1 right), the right upper lobe in 5 cases, the right lower lobe in 9 cases and the left lower lobe in the remaining 18 cases. Two patients did not have follow-up chest X-rays for the entire 48 h period: one patient in Group 2 died of non-respiratory complications after 24 h and one patient in Group 1, through inadvertent loss of the request form, did not have an X-ray at 48 h. The data for these two patients prior to this have been retained.

Figure 1 shows the mean percentage resolution of ALA for patients according to their allocated group. There was considerable variation in the profiles across time for individuals within groups, although the mean profiles for the groups were similar. The group \times time interaction was not significant, but there were significant effects for groups (ANOVA, $P<0.01$) and time ($P<0.01$). Fisher's least significant difference multiple comparisons were employed at the $P=0.05$ level for each time period to explore the nature of the differences between groups. After one treatment, patients in Group 1 had a significantly lower percentage resolution than patients in Groups 2, 3 and 4. At this time, patients in Group 2 had a significantly higher percentage resolution than patients in Group 5. No other significant differences existed between groups after one treatment. After 6 h, patients in both Groups 1 and 5 had a significantly lower percentage resolution than patients in Groups 3 and 4. There were no other differences between groups at 6 h. There were no significant differences between groups in the mean percentage resolution of ALA at 24 or 48 h. As the sample group was small and there was variability between patients, individual results of patients have been included (Figs 2-6).

To investigate whether the involvement of the left lower lobe was a confounding variable which adversely affected the outcome to treatment, the response of patients in each group according to whether or not the ALA involved the left lower lobe was analysed by including it as an extra factor in the ANOVA. The involvement of the left lower lobe did not significantly affect the

percentage resolution at any stage, nor did a combination of the group and left lower lobe involvement. Thus it would appear that left lower lobe ALA was not in itself an explanation for delayed resolution.

Thirty patients were intubated during the treatment period. The mean percentage resolution of ALA for all patients according to their intubation status is shown in Fig. 7. There were no significant differences in the percentage resolution of ALA between intubated and non-intubated patients at any time, although at 6 h the percentage resolution of ALA approached statistical significance (t -test, $P=0.059$), representing a lower percentage resolution for non-intubated patients. Twenty-four patients were mechanically ventilated during the treatment period, with the other 11 patients spontaneously ventilating. Figure 8 shows the percentage resolution for all patients according to their ventilation status. The percentage resolution was significantly lower at 6 h for patients who were spontaneously ventilating (t -test, $P=0.04$). There were no other significant differences in the resolution of ALA between mechanically ventilated and spontaneously ventilating patients. Air bronchograms were detected on seven diagnostic chest X-rays (Group 1, $n=2$; Group 2, $n=1$; Group 3, $n=2$; Group 4, $n=1$; Group 5, $n=1$). There were no significant differences in the percentage resolution of ALA between patients with or without air bronchograms on their diagnostic chest X-rays.

When all patients were considered together, the mean partial pressure of oxygen in arterial blood divided by the FiO_2 ($\text{PaO}_2/\text{FiO}_2$) was not significantly altered on the day of diagnosis of ALA from the value obtained on the previous day (mean value 95.2%). At 6 h, the mean $\text{PaO}_2/\text{FiO}_2$ had significantly increased to 122.8% of the value obtained at the time of diagnosis (t -test, $P=0.02$). At 24 and 48 h, there was further significant improvement to means of 125.6% and 128.5% respectively of the value obtained at the time of diagnosis (t -test, $P=0.007$ at 24 h and 0.04 at 48 h). The mean $\text{PaO}_2/\text{FiO}_2$ values by group are given in Table 2. There were no significant differences between groups in these values or any other ABG parameters at any stage.

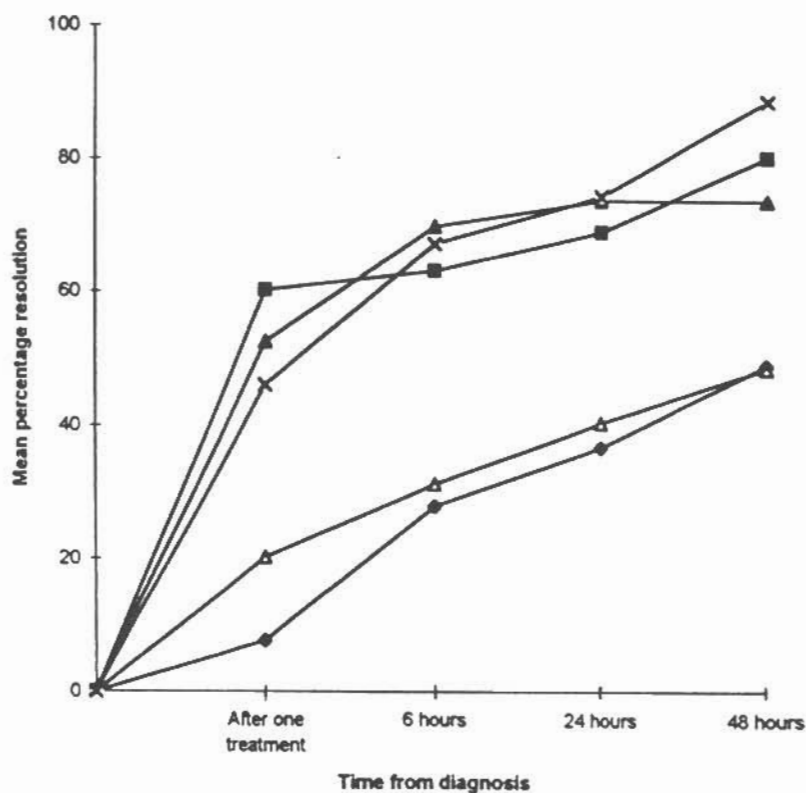


Fig. 1 Mean percentage resolution of acute lobar atelectasis by group. ♦, Group 1; ■, Group 2; ▲, Group 3; x, Group 4, △, Group 5.

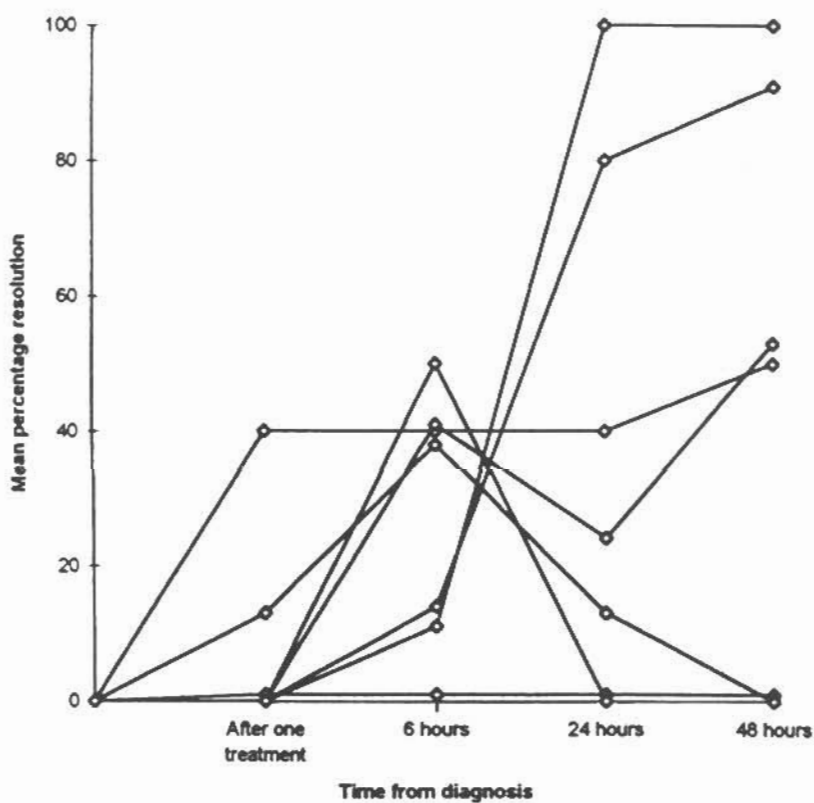


Fig. 2 Mean percentage resolution for individual patients in Group 1.

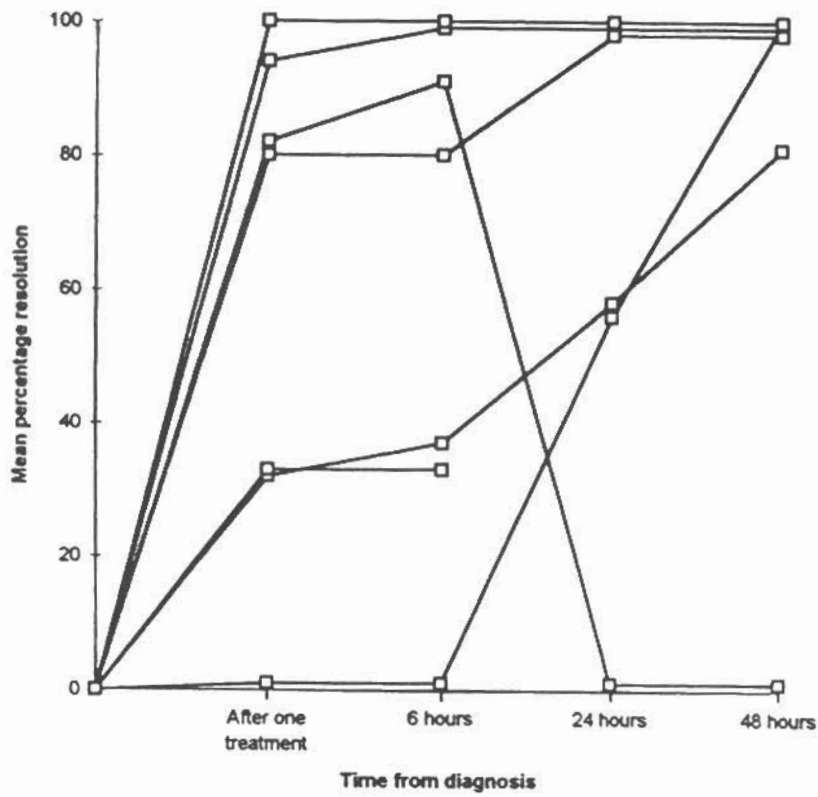


Fig. 3 Mean percentage resolution for individual patients in Group 2.

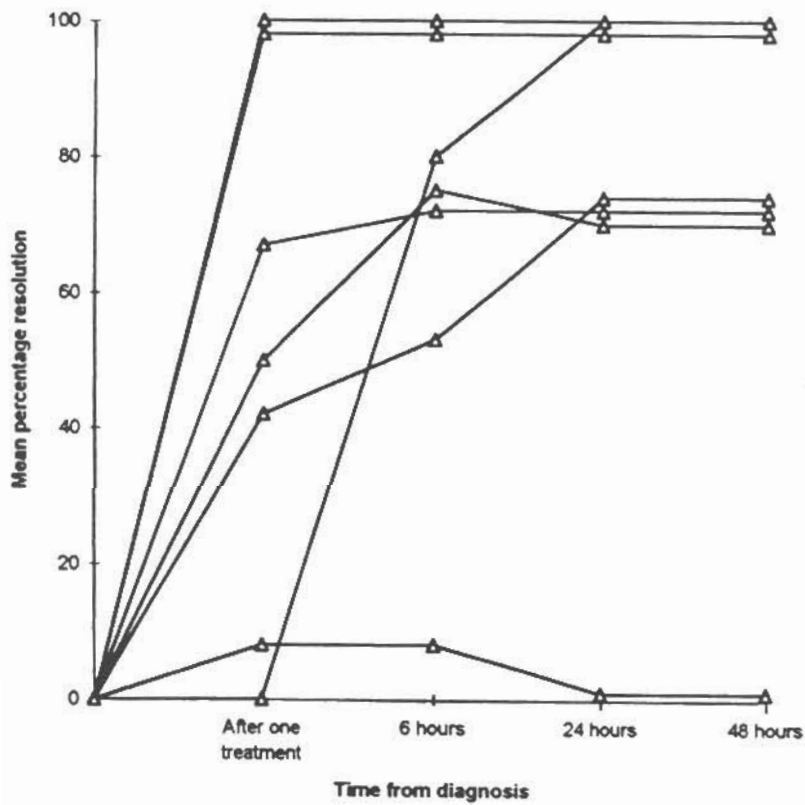


Fig. 4 Mean percentage resolution for individual patients in Group 3.

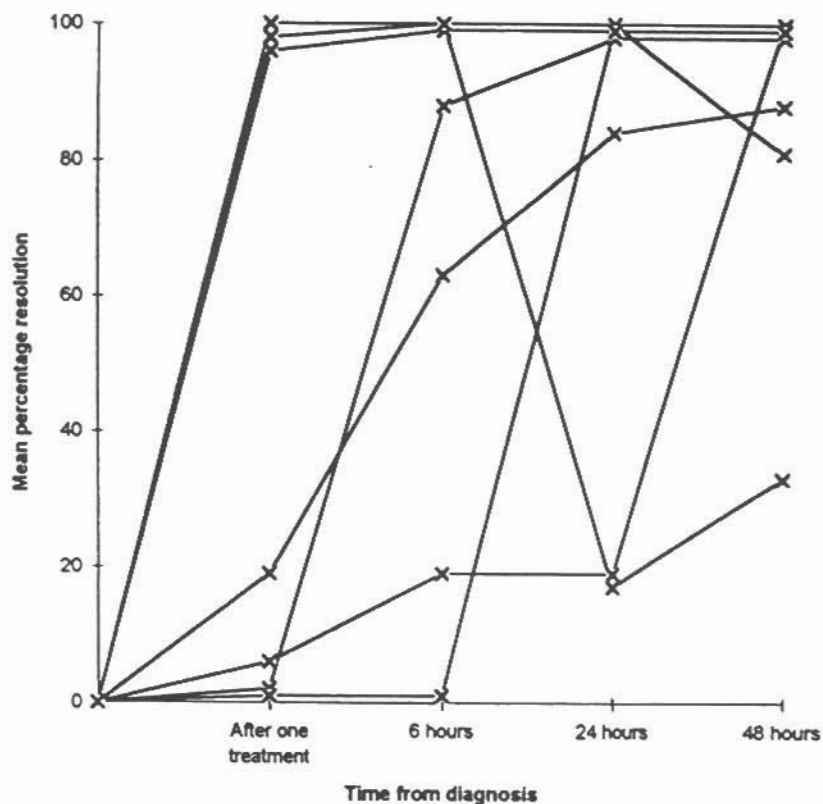


Fig. 5 Mean percentage resolution for individual patients in Group 4.

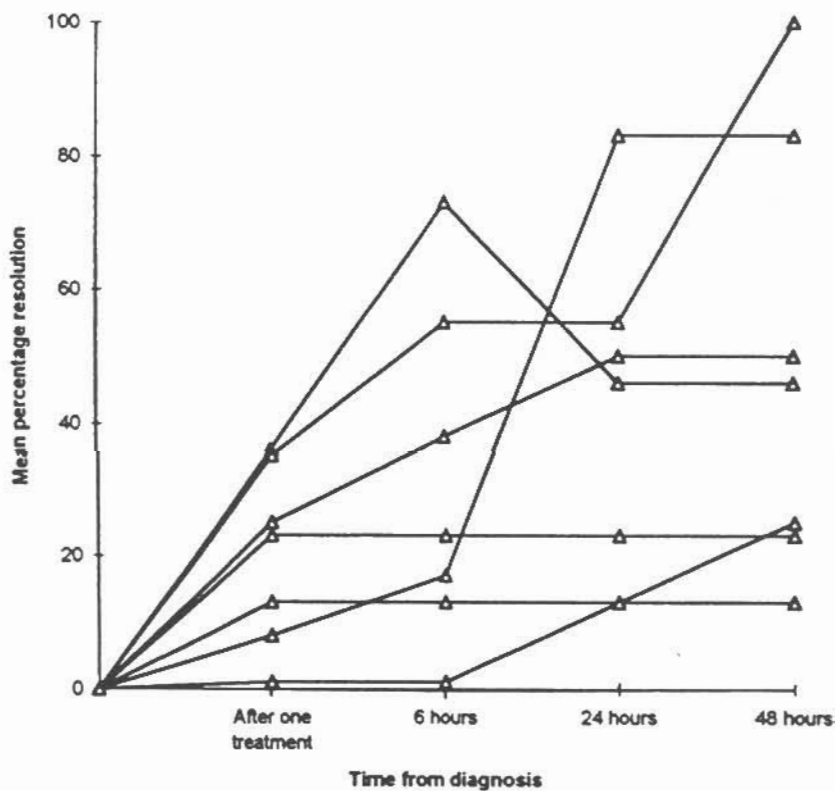


Fig. 6 Mean percentage resolution for individual patients in Group 5.

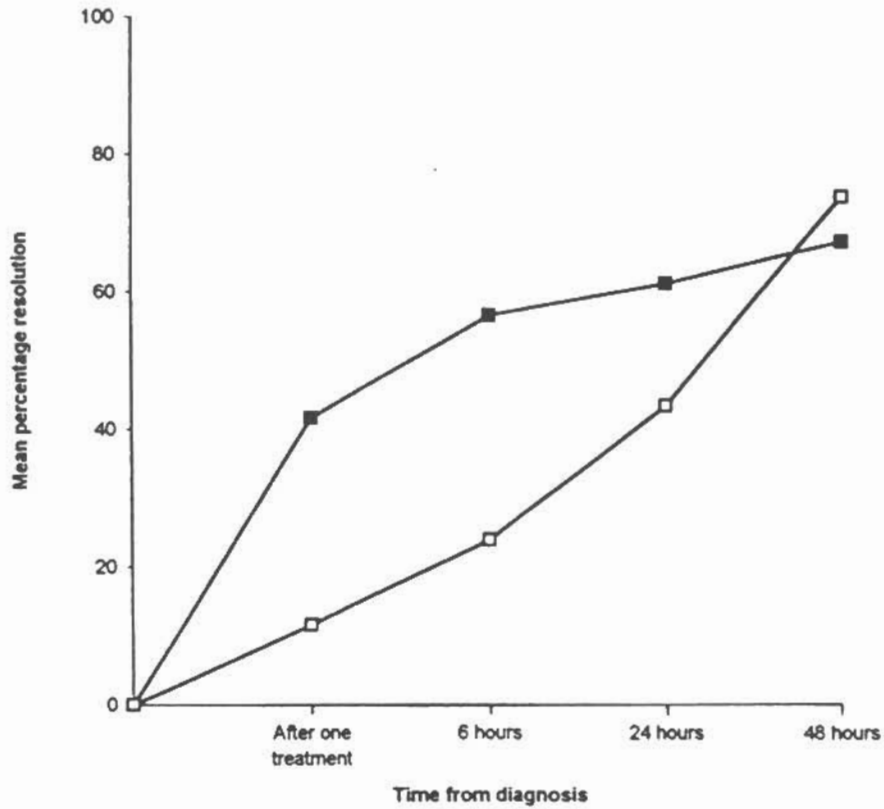


Fig. 7 Mean percentage resolution of acute lobar atelectasis according to intubation status. ■, Intubated patients (n=30); □, non-intubated patients (n=5).

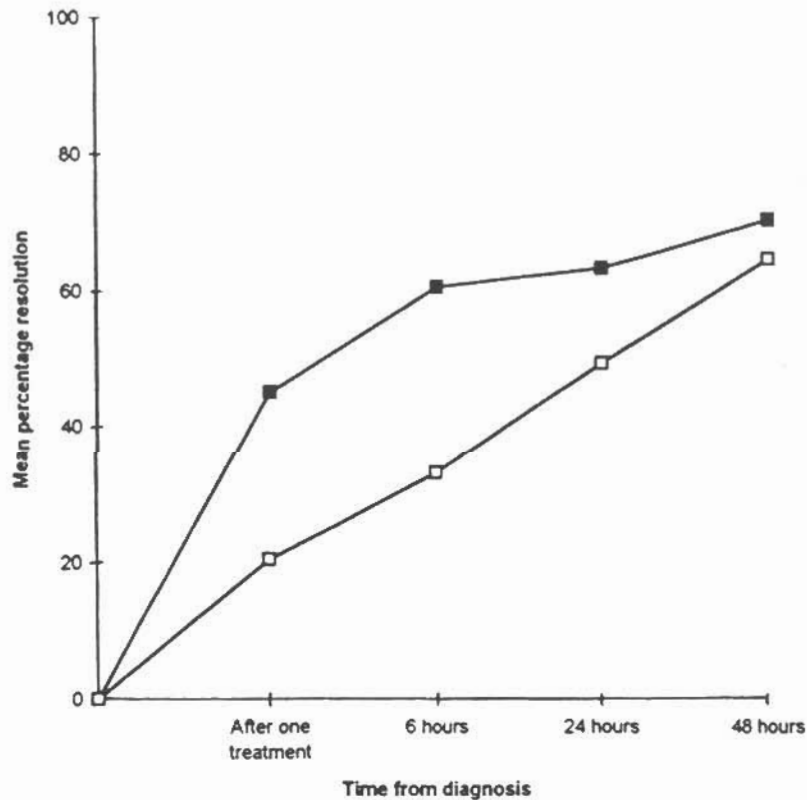


Fig. 8 Mean percentage resolution of acute lobar atelectasis according to ventilation status. ■, Mechanically ventilated patients (n=24); □, spontaneously ventilating patients (n=11).

There was little change in the mean rectal temperature over the study period (Table 2). At 24 h, patients in Group 4 had a significantly lower temperature than patients in Groups 3 and 5 (F -test, $P=0.048$). There were no other significant differences between groups at any other times, nor were there any significant differences between groups in the white cell count at any stage or the sputum volume obtained during the treatment period (although this approached statistical significance: F -test, $P=0.057$; representing a lower volume of sputum for patients in Groups 4 and 5 compared with patients in Group 2) (Table 2). Sputum culture was performed for 28 patients on the sputum collected during treatment and bacterial contamination detected for 13 patients (Group 1, $n=3$; Group 2, $n=4$; Group 3, $n=3$; Group 4, $n=2$; Group 5, $n=1$). The mean percentage resolution of ALA for the 28 patients who had sputum cultures performed showed no significant difference between those patients with positive or negative sputum culture results.

All but 2 of the 35 patients were medically stable throughout the treatment period. Of the two patients whose medical condition was unstable, one patient in Group 2 demonstrated

marked cardiovascular instability, not associated with physiotherapy treatment, but as a result of acute renal and cardiac failure. This patient died 24 h after the diagnosis of ALA as a result of multisystem failure. The other medically unstable patient (Group 3) was profoundly hypoxaemic at the time of diagnosis of left lower lobe ALA, with episodic oxygen desaturation not associated with physiotherapy treatment. In this patient, the ALA showed 80% resolution after 6 h, with a 173% improvement in $\text{PaO}_2/\text{FiO}_2$ at this time compared with the initial value. This patient subsequently developed adult respiratory distress syndrome from which she ultimately recovered. Although 16 patients had undergone surgery prior to development of ALA, all were considered stable from a surgical point of view during the treatment period.

DISCUSSION

A limitation of the present study was the small sample tested, but only 35 patients satisfied the strict inclusion criteria over a period of almost 6 years. During this time, a similar number of patients with ALA had to be excluded from the

Table 2
Oxygenation, sputum volume, rectal temperature and white cell count by group*

	Group 1	Group 2	Group 3	Group 4	Group 5
$\text{PaO}_2/\text{FiO}_2$(%)^b					
Diagnosis (% pre-diagnosis)	109.9 ± 16.6	83.8 ± 18.0	118.9 ± 16.6	77.1 ± 16.6	83.2 ± 18.0
6 h (% diagnosis)	93.2 ± 18.7	129.7 ± 18.7	116.7 ± 18.7	170.2 ± 18.7	100.4 ± 20.5
24 h (% diagnosis)	106.1 ± 18.8	135.2 ± 20.3	106.3 ± 18.8	159.2 ± 20.3	127.7 ± 20.3
48 h (% diagnosis)	118.2 ± 27.2	145.0 ± 30.4	111.2 ± 27.2	186.0 ± 30.4	102.0 ± 24.8
Sputum volume (ml)	12.9 ± 3.3	15.0 ± 3.3	10.7 ± 3.3	3.6 ± 3.3	3.6 ± 3.3
Rectal temperature (°C)					
Pre-diagnosis	37.8 ± 0.4	37.1 ± 0.4	37.9 ± 0.4	37.5 ± 0.4	37.4 ± 0.4
Diagnosis	37.6 ± 0.3	37.7 ± 0.3	37.6 ± 0.3	37.1 ± 0.3	37.8 ± 0.3
24 h	37.3 ± 0.3	37.3 ± 0.3	37.9 ± 0.3	36.9 ± 0.3	37.9 ± 0.3
48 h	37.5 ± 0.3	37.3 ± 0.3	37.8 ± 0.3	37.0 ± 0.3	37.9 ± 0.3
White cell count (× 10³ mm⁻³)					
Pre-diagnosis	14.6 ± 1.9	14.6 ± 2.0	13.2 ± 1.9	12.3 ± 1.9	11.7 ± 1.9
Diagnosis	14.6 ± 1.9	15.6 ± 1.8	13.7 ± 1.8	9.1 ± 1.9	11.7 ± 1.8
24 h	13.6 ± 2.0	17.4 ± 2.4	16.1 ± 2.0	9.3 ± 2.2	11.6 ± 2.0
48 h	14.4 ± 2.3	17.3 ± 2.5	18.9 ± 2.3	9.3 ± 2.8	11.3 ± 2.1

*Values are means ± standard errors.

^b $\text{PaO}_2/\text{FiO}_2$ = partial pressure of oxygen in arterial blood/inspired fraction of oxygen expressed as a percentage of the pre-diagnostic or diagnostic value. The values for $\text{PaO}_2/\text{FiO}_2$ obtained at the time of diagnosis have been expressed as a percentage of the pre-diagnostic values, while those obtained at 6, 24 and 48 h have been expressed as a percentage of the diagnostic values.

study. Despite the limited sample, it was possible to obtain results that were statistically and, we believe, clinically significant.

This study found that the mean rate of resolution of ALA for patients who received modified postural drainage, with or without vibrations (Groups 2 or 3), or postural drainage (Group 4), in addition to manual hyperinflation (or deep breathing) and suction (or coughing and huffing) hourly for 6 h was statistically significantly better after one treatment than that of patients who received hourly manual hyperinflation and suction alone for 6 h (Group 1). The mean percentage resolution remained significantly better for patients in Groups 3 and 4 compared with those in Group 1 at 6 h. Thus from the limited data obtained, it would appear that modified postural drainage, with or without vibrations, is an effective additional component to manual hyperinflation and suction. As no significant difference existed between Groups 2 and 3 at any stage, it would seem that vibrations can be omitted without any loss of effect on resolution of ALA. As patients in Group 4 who received traditional postural drainage instead of modified postural drainage did not have a significantly different rate of resolution from patients in Group 3 at any time, it would appear that modified postural drainage is as effective as traditional postural drainage in the treatment of ALA. Group 5 patients who received the same components of treatment as patients in Group 3, but received one treatment only, had a significantly lower percentage resolution than Group 2 patients after one treatment and Group 3 and 4 patients after 6 h. This suggests that hourly treatment for 6 h is more effective than one treatment only.

Clinicians wish to achieve full resolution of ALA as quickly as possible to avoid the complications and delayed recovery which are believed to result from persistent ALA (Marini et al, 1979). As such, the superior rate of resolution for the patients in Groups 2, 3 and 4 after one treatment and at 6 h would probably be considered clinically significant. Although no statistically significant difference was detected between the groups at 24 and 48 h, the mean percentage resolution of patients in Groups 2, 3 and 4 was still approximately 30% greater than

that of patients in Groups 1 and 5. Whether this represents a clinically significant difference is not clear. Other parameters measured at 24 and 48 h (i.e. PaO₂, rectal temperature and white cell count) did not reveal any significant differences between groups which would indicate a worse outcome for patients in Groups 1 or 5. Thus, although it cannot be stated with certainty, there was no indication that the use of a basic treatment regimen or one treatment only increased the associated morbidity at 24 and 48 h.

For ethical reasons it was not possible to include a control group of patients who received no physiotherapy treatment. However, if patients received no treatment, it is unlikely that their ALA would resolve as quickly as that of patients in this study who received the additional physiotherapeutic techniques. It is not possible to say though, from the results of this study, if the ALA of patients who received no treatment would resolve any more slowly than that of patients who received a basic treatment regimen only (Group 1).

As suggested in our earlier study (Stiller et al, 1990), there was evidence, in particular at 6 h, that patients who were not intubated and/or spontaneously ventilating had a slower rate of resolution of ALA. As ALA is believed to occur as a result of airway obstruction, decreased regional ventilation and/or reduced pulmonary compliance, this is not surprising given that intubation allows airway access for more effective airway clearance and mechanical ventilation should assist in improved regional ventilation.

Although postural drainage (both traditional and modified) and chest wall vibrations were used with the intention of increasing clearance of sputum, the volume of sputum cleared during treatment was not significantly different between groups. Thus it could be hypothesised that the improved resolution of ALA seen in the groups which received these additional components of treatment was not due to improved sputum clearance (and thus decreased airway obstruction). Instead, it may be due to the effects of these techniques on the other factors which are believed to cause ALA (i.e. decreased regional ventilation and pulmonary compliance). This hypothesis remains to be proven.

Similarly, the mechanisms of effect of the other techniques used in this study are also unclear for a number of reasons. First, in the clinical setting there is no definitive way of identifying the exact cause of ALA and, in many instances, the cause is probably multifactorial. Secondly, the treatment techniques used in this study are likely to act on more than one mechanism (e.g. manual hyperinflation may improve regional ventilation, increase pulmonary compliance and assist in the removal of airway obstruction). Thus all that can be surmised at present is that a combination of techniques appears to be effective in overcoming the cause of ALA.

Another important point is the way in which the duration of the specific treatment techniques was decided. In the interest of standardising the treatment regimens to allow replication of the study, postural drainage and vibrations were given for a set time period. While it could be argued that the duration of application of these techniques should have been based on each subject's clinical response rather than time, it was not possible to identify any variables, either from previous studies or clinical experience, that could be used to measure the individual effect of the techniques at the actual time of treatment. On the contrary, it was possible to make a decision at the time regarding the number of suction 'passes' or repeated coughs required during any one treatment session based on clinical grounds (i.e. whether or not secretions were still being cleared). Another reason for placing a time limit on the duration of postural drainage and vibrations was that unduly long treatments were undesirable because the treatment sessions were given hourly for 6 h (except for Group 5). Further studies are needed to determine whether techniques, such as vibrations, may be more effective if given for a longer period of time.

As noted earlier, the study lasted almost 6 years, with recruitment to Groups 1 and 2 occurring during the first 19 months and to Groups 3, 4 and 5 during the last 4 years (approximately). The rate of recruitment remained at a fairly constant level during this time. While general changes in patient care undoubtedly occurred during this time, the standardisation of treatment

regimens should make the comparison of groups valid despite the time lapse.

The similarities between the rate of resolution of ALA achieved in the present study and in that of Marini et al (1979) are striking, despite the differences in study design, populations studied and examiners involved in measuring the chest X-rays. It would appear that the hourly treatment for 6 h of patients in Groups 2, 3 and 4 was no less effective than the less frequent but longer duration treatment (treatment every 4 h for 48 h) used by Marini et al (1979). However, unlike Johnson et al (1987), we found that at least initially in the course of ALA, a treatment of manual hyperinflation and suction (or deep breathing, coughing and huffing) was enhanced by the addition of postural drainage (modified or not), with or without vibrations. As the details of the study by Johnson et al (1987) are lacking, the reason for this contradiction in results is unclear. In view of the differing ways in which the degree of ALA was evaluated, it is difficult to make meaningful comparisons between the present study and other studies which have evaluated the effect of various treatments on the resolution of ALA, although most authors have noted improvements after treatment (Wanner et al, 1973; Fowler, Scoggins and O'Donohue, 1978; Mahajan, Catron and Huber, 1978; O'Donohue, 1979; Perruchoud et al, 1980; Hammon and Martin, 1981; Harris, 1985; Murray, 1985; Duncan et al, 1987).

Although the results of this study need to be validated in a larger patient population, the study provides evidence that will assist in the selection of physiotherapy techniques in the treatment of ALA. At least initially in the course of ALA, a treatment of manual hyperinflation and suction is enhanced by the addition of postural drainage or modified postural drainage, with or without vibrations, performed hourly for 6 h. It would appear that hourly treatment for 6 h using modified postural drainage, manual hyperinflation and suction is more effective than one treatment only.

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References

- Benjamin JJ, Cascade PN, Rubenfire M, Wajszczuk W, Kerin NZ 1982 Left lower lobe atelectasis and consolidation following cardiac surgery: The effect of topical cooling on the phrenic nerve. *Radiology* 142: 11-14
- Duncan SR, Negrin RS, Mihm FG, Guilleminault C, Raffin TA 1987 Nasal continuous positive pressure in atelectasis. *Chest* 92: 621-624
- Fowler AA, Scoggins WG, O'Donohue WJ 1978 Positive end-expiratory pressure in the management of lobar atelectasis. *Chest* 74: 497-500
- Haas M 1991a The reliability of reliability. *Journal of Manipulative and Physiological Therapeutics* 14: 199-208
- Haas M 1991b Statistical methodology for reliability studies. *Journal of Manipulative and Physiological Therapeutics* 14: 119-132
- Hammon WE, Martin RJ 1981 Chest physical therapy for acute atelectasis. *Physical Therapy* 61: 217-220
- Harris RS 1985 The importance of proximal and distal air bronchograms in the management of atelectasis. *Journal of the Canadian Association of Radiologists* 36: 103-109
- Johnson NT, Marini JJ, Pierson DJ, Hudson LD 1987 Acute lobar atelectasis: Effect of chest percussion and postural drainage (CPPD) on resolution. *American Review of Respiratory Disease* 135: A433
- Large SR, Heywood LJ, Flower CD, Cory-Pearce R, Wallwork J, English TAH 1985 Incidence and aetiology of a raised hemidiaphragm after cardiopulmonary bypass. *Thorax* 40: 444-447
- Mahajan VK, Catron PW, Huber GL 1978 The value of fiberoptic bronchoscopy in the management of pulmonary collapse. *Chest* 73: 817-820
- Marini JJ, Pierson DJ, Hudson LD 1979 Acute lobar atelectasis: A prospective comparison of fiberoptic bronchoscopy and respiratory therapy. *American Review of Respiratory Disease* 119: 971-978
- Markand ON, Moorthy SS, Mahomed Y, King RD, Brown JW 1985 Postoperative phrenic nerve palsy in patients with open-heart surgery. *Annals of Thoracic Surgery* 39: 68-73
- Murray JF 1985 Treatment of acute total atelectasis. *Anaesthesia* 40: 158-162
- O'Donohue WJ 1979 Maximum volume IPPB for the management of pulmonary atelectasis. *Chest* 76: 683-687
- Perruchoud A, Ehrsam R, Heitz M, Kopp C, Tschann M, Herzog H 1980 Atelectasis of the lung: Bronchoscopic lavage with acetylcysteine. Experience in 51 patients. *European Journal of Respiratory Disease* 61: 163-168
- Shrout P, Fleiss J 1979 Intraclass correlations: Uses in assessing rater reliability. *Psychological Bulletin* 86: 420-428
- Stiller K, Geake T, Taylor J, Grant R, Hall B 1990 Acute lobar atelectasis: A comparison of two chest physiotherapy regimens. *Chest* 98: 1336-1340
- Wanner A, Landa JF, Nieman RE, Vevaina J, Delgado I 1973 Bedside bronchofiberscopy for atelectasis and lung abscess. *Journal of the American Medical Association* 224: 1281-1283
- Webber BA 1988 *The Brompton Hospital guide to chest physiotherapy*, 5th edn, p 33. Blackwell Scientific, London