Effects of deep breathing exercises and ambulation on pattern of ventilation in post-operative patients

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Deep breathing and ambulation are used by physiotherapists for patients after surgery, however the precise effects of these on ventilation have not been investigated. This study was designed to compare the effects of deep breathing and ambulation on pattern of breathing in patients after upper abdominal surgery. A similar increase was found in minute ventilation, however the pattern of breathing seen during each treatment was very different. During the deep breathing exercises patients had large, significant increases in tidal volume (mean change 488.5mL), while respiratory rate decreased non-significantly. By comparison, ambulation caused small and non-significant increases in both tidal volume (163.4mL) and respiratory rate. It appears that if one of the aims of ambulation is to increase tidal volume, patients may need to be encouraged to augment their tidal volumes. [Orfanos P, Ellis ER and Johnston C (1999): Effects of deep breathing exercises and ambulation on pattern of ventilation in post-operative patients. Australian Journal of Physiotherapy 45: 173-182.]

Key words: Breathing Exercises; Early Ambulation; Post-operative Period; Ventilation

Introduction

Atelectasis commonly occurs following major surgery (Brooks-Brunn 1995) and physiotherapists have an important role in treating atelectasis and trying to prevent its progression to more clinically significant pulmonary complications (Celli et al 1984, Roukema et al 1988). Two major causes of post-operative atelectasis are breathing with a rapid and shallow pattern of breathing (Ali et al 1974, Zikria et al 1974) and a reduced functional residual capacity (FRC) (Ali et al 1975, Meyers et al 1975). In an effort to treat atelectasis, physiotherapists aim to improve the patient’s pattern of breathing and to increase FRC by using deep breathing exercises and ambulation in the post-operative period.

There have been few studies that have compared the effectiveness of deep breathing exercises and ambulation in preventing post-operative pulmonary complications. Two studies conducted in patients following upper abdominal surgery found that deep breathing exercises were more effective than ambulation alone in preventing post-operative pulmonary complications (Celli et al 1984, Roukema et al 1988). Three studies conducted in patients after cardiac surgery found that deep breathing exercises offered no advantage over ambulation alone in the prevention of post-operative pulmonary complications (Dull and Dull 1983, Jenkins et al 1989, Stiller et al 1994). Based on the results of the cardiac surgery studies, it is possible that physiotherapists may choose to use ambulation on its own in wider post-operative populations. However, the precise effects of deep breathing exercises and ambulation on pattern of ventilation have not been fully investigated. Only one study (Jenkinset al 1989) has investigated the effects of ambulation on FRC and found that the addition of deep breathing did not confer any additional benefit in increasing FRC. The main purpose of our study therefore was to compare the effects of deep breathing exercises and ambulation on the pattern of breathing in patients after upper abdominal surgery. In addition, an attempt was made to investigate the effects of positioning on pattern of breathing and whether deep breathing exercises and ambulation have any carry-over effects on pattern of breathing.

Methods

This study was designed for repeated measures on the same subjects under two different conditions: during deep breathing exercises and ambulation on consecutive days. The two treatments were systematically alternated to avoid an order effect. Testing was carried out in the general and high
dependency surgical wards at Westmead Hospital, Sydney. Ethical approval for this study was obtained from the Ethics Committees of The University of Sydney and the Western Sydney Area Health Service.

**Subjects** Nineteen consecutive adult patients admitted to Westmead Hospital for elective or emergency upper abdominal surgery were considered for the study. Upper abdominal surgery was defined as surgery involving an incision which extended cranially above the umbilicus but which did not enter the thorax (Celli et al. 1984). Where possible, patients were recruited pre-operatively, or in the first two days after surgery. Patients were given an information sheet to read before written, informed consent was obtained.

**Protocols** Patients acted as their own control and received either deep breathing exercises or ambulation at the same time of day on two separate and preferably consecutive days (on their third to fifth post-operative day). Three other potentially confounding variables were identified: level of activity before each testing session, amount of pain before and during each testing session, and type and amount of pain medication taken before each testing session. In order to control for these variables, patients were instructed to remain in bed for two hours prior to testing, and to refrain from exercising or performing any breathing exercises during this time. Half an hour before testing started, patients were asked to rate their pain level on a numerical rating scale (between 0 and 10). At this time, patients were encouraged to obtain adequate pain relief before the start of each treatment and the type and amount of pain medication patients had taken prior to each testing session was recorded.

For the deep breathing exercises, patients were required to perform a series of deep breaths under the supervision of the same physiotherapist. Patients were instructed to breathe in as slowly and deeply as they could, and to breathe out in a relaxed manner. An inspiratory hold was not added to the breathing exercises. Patients performed five or six deep breaths, with the physiotherapist using proprioceptive input to encourage the patient to make each breath deeper than the last. Following a rest period (normal breathing), the cycle was repeated five times. Measurement of pattern of breathing took place during the last two cycles. The entire treatment lasted approximately five or six minutes. The breathing exercises were performed by the patient sitting upright, either over the side of the bed or in a chair.

For the ambulation, patients were required to walk along the flat corridor in their ward. Patients were instructed to walk at a comfortable pace, and to
continue for as long as they felt they could. Patients were accompanied by the same therapist, who gave assistance with attachments as necessary. This treatment also lasted for approximately five or six minutes. For this intervention, pattern of breathing was measured towards the end of the corridor walk, while patients walked on the spot.

**Measurement of pattern of breathing** Pattern of breathing was measured on five separate occasions during each testing session and included minute ventilation, tidal volume, respiratory rate and inspiratory flow rate. Patients were not told which particular breathing parameters were being measured.

A resting measure was taken when patients were lying in bed (usually in a semi-recumbent position). In order to separate the effects of changing position from the effects of the actual treatment, a measure was taken once patients were in the position in which they would receive their treatment - that is, a measure was taken once the patient was sitting up (either over the side of the bed or in a chair) before beginning the breathing exercises, or once the patient was standing before ambulation. In both of these instances, patients were given a few minutes to recover from the change in body position before measurement began. Pattern of breathing was also measured during the final two minutes of each treatment. In order to determine whether the treatments had any carry-over effect, pattern of breathing was measured at five minutes and 30 minutes after treatment while patients were either resting back in bed or sitting in a chair. For each of these measurement periods, pattern of breathing was measured continuously for two minutes.

**Equipment** Patients breathed through a face-mask which was attached to a pneumotachograph (Model 3813, Hans Rudolph Inc. Kansas City USA) which measures bi-directional airflow. The airflow signal was analysed and recorded by a computerised Pulmonary Data Acquisition and Analysis System (PulSys Version 1.2, Clinical Engineering Solutions). Before each test the system was calibrated using a 3L calibration syringe (Vacumetrics, Ventura, California, Model 1092) according to the American Thoracic Society Guidelines (Pierce 1986). The reliability of the pneumotachograph is ±0.02 cm H₂O (Hans Rudolph Inc. 1988). Signals from each breath detected by the pneumotach were recorded as the respiratory rate, volume, minute ventilation and inspiratory flow rate for each breath. Respiratory data collected were corrected for room temperature, pressure and humidity.

Mean values for each parameter of pattern of breathing were calculated for each of the measurement periods, using the entire two minutes of
recorded breaths. To analyse the data statistically, a number of post-hoc comparisons were performed on SPSS for Windows and special purpose software to carry out one-way ANOVA for repeated measures (Winer 1991), with the measurement period being the repeat factor. The initial significance level was set at $p = 0.05$. When making multiple post-hoc comparisons, if enough comparisons are made, a significant result may be obtained by chance (Hays 1994), that is, there is a greater chance of making a Type I error. In order to keep the overall Type I error at 0.05, the significance level of each of the 10 comparisons was adjusted to $p = 0.005$ using the Bonferroni method (Winer 1991). At this level, each comparison needed a critical $F$ of greater than 11.06 to reach statistical significance.

**Results**

Fifteen patients completed the study out of the 19 who initially agreed to participate. The reasons for withdrawal were: ambulation contraindicated (one patient) and inability to co-operate (three patients). The mean age of the 15 participants was 48.7 years (range, 17 to 71). Six of the 15 patients were smokers, six were ex-smokers with a mean (SD) pack/year history of 16.8 (15.3), and three were non-smokers. The types of surgery included removal or resection of part of the colon or rectum (9 patients); small bowel resection (3); nephrectomy (1); cholecystectomy (1) and removal of the pancreas and duodenum (1). Of the 15 patients, three belonged to the ASA (American Society of Anesthesiologists Classification of Physical Status) Class I (a normal healthy patient), nine to Class II (a patient with mild systemic disease), and three to Class III (a patient with severe systemic disease).
disease that limits activity but is not incapacitating) (ASA 1963).

Upon analysis, there were no appreciable differences between the two treatments for the confounding variables: previous level of activity, amount of pain, or amount of pain medication taken.

Both deep breathing exercises and ambulation significantly increased minute ventilation ($F_{(1,14)} = 26.06, p < 0.005; F_{(1,14)} = 21.63, p < 0.005$ respectively, Figure 1), and there was no significant difference between the extent to which each treatment increased minute ventilation ($F_{(1,14)} = 0.04, p > 0.1$). However, the way in which the increase in ventilation was achieved during each treatment was very different. During the deep breathing exercises, minute ventilation was increased predominantly through a significant doubling in tidal volume ($F_{(1,14)} = 55.00, p < 0.005$, Figure 2). Respiratory rate during the deep breathing exercises, on the other hand, decreased non-significantly ($F_{(1,14)} = 3.22, p < 0.1$). By comparison, the increase in minute ventilation during ambulation was achieved by small and non-significant increases in both tidal volume (an increase of only 33 per cent) and respiratory rate ($F_{(1,14)} = 9.18, p < 0.01; F_{(1,14)} = 7.05, p < 0.025$ respectively, Figure 3).

Positioning alone had a great effect on pattern of breathing (Figure 3). The largest effect was seen when the patients stood, which accounted for 65 per cent of the increase in minute ventilation seen during ambulation. Once patients were standing, the additional increase in minute ventilation seen during ambulation was not significant ($F_{(1,14)} = 4.79, p < 0.05$).

Neither deep breathing exercises nor ambulation had a significant carry-over effect on minute ventilation after treatment ($F_{(1,14)} = 4.16, p < 0.1; F_{(1,14)} = 1.88, p > 0.1$, respectively, Figure 4). Deep breathing exercises had a significant carry-over effect on both tidal volume and respiratory rate ($F_{(1,14)} = 12.08, p < 0.005; F_{(1,14)} = 13.62, p < 0.005$ respectively, Figures 5 and 6). That is, after the deep breathing exercises, patients were breathing with a larger tidal volume and a slower respiratory rate than during rest. In contrast, ambulation did not have any significant carry-over effect after treatment on either tidal volume or respiratory rate ($F_{(1,14)} = 1.38, p > 0.1; F_{(1,14)} = 0.33, p > 0.1$, respectively, Figures 5 and 6).

An additional finding of this study was that although deep breathing exercises reduced respiratory rate, inspiratory flow rate increased significantly during this treatment ($F_{(1,14)} = 11.56, p < 0.005$) (Figure 7). As inspiratory flow rate also increased significantly during ambulation ($F_{(1,14)} = 16.08, p < 0.005$) there was no significant difference between the effects of deep breathing exercises and ambulation on inspiratory flow rate ($F_{(1,14)} = 0.18, p > 0.1$).

The mean values presented for pattern of breathing during the deep breathing exercises treatment have been an average of both the coached deep breaths and quiet breathing. When the coached deep breaths are separated from the quiet breathing, it is evident that deep breathing exercises had an even more dramatic effect on pattern of breathing (Table 1). Minute ventilation during the coached deep breaths was almost three times greater than at resting level. Tidal volume during the coached deep breaths was almost

<table>
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<th>Quiet breathing</th>
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<td>Minute ventilation (L/min)</td>
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<td>Tidal volume (mL)</td>
<td>373.4 (204.3)</td>
<td>861.9 (247.0)</td>
<td>1415.5 (363.2)</td>
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<td>Respiratory rate (Breaths/min)</td>
<td>21.3 (4.3)</td>
<td>19.2 (1.0)</td>
<td>14.1 (2.9)</td>
<td>22.5 (5.7)</td>
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<tr>
<td>Inspiratory flows (mL/s)</td>
<td>372.8 (206.0)</td>
<td>543.2 (124.1)</td>
<td>701.0 (44.6)</td>
<td>371.6 (29.6)</td>
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Table 1. Comparisons of mean (and standard deviations) of ventilatory pattern during rest and overall treatment period to those values during coached deep breaths and quiet breathing.
four times greater than at resting level, and respiratory rate fell by more than seven breaths per minute. Inspiratory flow rate increased further during the coached deep breaths. In contrast, pattern of breathing during quiet breathing very closely resembled pattern of breathing at rest.

Discussion

One of the reasons patients are encouraged to walk post-operatively is because walking, by increasing functional residual capacity (FRC) and increasing minute ventilation, is believed to increase regional ventilation to the dependent lung units. While the effect of ambulation on FRC has been measured in normal subjects (Blair and Hickam 1955), the effect of post-operative ambulation on minute ventilation has not directly been measured. This study shows that ambulation does not significantly increase minute ventilation once the effects of position are taken into consideration.

The most likely explanation for ambulation not significantly increasing minute ventilation is that post-operative patients are not being exercised at a high enough intensity. Despite the fact that one of the aims of post-operative ambulation is to increase minute ventilation, little attention is given in the clinical setting to the intensity at which patients are being walked and to whether ambulation is actually increasing minute ventilation significantly. Currently, it is common clinical practice to walk patients along the corridor according to very subjective limits. Rarely are objective measures such as heart rate or respiratory rate used to prescribe a minimum intensity. Rather, such measures are used as a precaution against over-exerting patients. There is a view in the literature that such a non-specific approach to the ambulation of post-operative patients is probably not an effective use of the physiotherapist’s expertise and time (Dean 1994, Haskell 1985, Ross and Dean 1989). It has also been recommended that a more structured approach needs to be taken in the ambulation of post-operative patients in order to make the intervention more effective (Dean and Ross 1992a, Haskell 1985).

Another methodological factor may have contributed to the apparently low minute ventilation seen during ambulation. Pattern of breathing during ambulation was measured while patients walked on the spot, towards the end of their corridor walk. It may be that a higher level of minute ventilation would have been recorded if pattern of breathing was measured while patients walked along the corridor.

The findings of this study support the view that post-operative ambulation could be made more effective in significantly increasing minute ventilation by giving more attention to the intensity of the stimulus being provided, in order to ensure that the intervention patients receive is effective as well as safe. As yet, specific guidelines for mobilising and ambulating acute post-operative patients are lacking (Dean and Ross 1992a). Clearly, further research is needed to help refine the prescription of post-operative ambulation, so that maximal therapeutic benefit can be gained with the least risk (Dean and Ross 1992b, Jenkins 1991).

It is generally accepted that it is important to increase patients’ tidal volumes post-operatively in order to affect atelectasis (Bartlett et al 1971, Chuter et al 1990, Marini 1984, O’Donohue 1992). Studies conducted more than 30 years ago have shown that while breathing with a shallow and rapid tidal volume produces gradual alveolar collapse within one hour (Caro et al 1960, Egbert and Bendixen 1964), taking deep breaths is able to reverse alveolar collapse (Ferris and Pollard 1960). Such findings led to the common use of deep breathing exercises in the post-operative period, since they encourage patients to take deep breaths, and have been shown to be effective (Chuter et al 1990).

It is a common clinical perception reflected in the literature (Dean 1993, Scheidegger et al 1976) that early post-operative ambulation, as well as significantly increasing minute ventilation, is also able to significantly increase tidal volume. As a result of this idea, there are also some clinicians who believe that if patients are able to walk, there is no need for them to perform deep breathing exercises. The belief that ambulation may have a somewhat similar effect to deep breathing exercises on tidal volume has perhaps been reinforced by the findings of studies conducted in patients following cardiac surgery, which concluded that deep breathing exercises offer no advantage over ambulation alone in the prevention of post-operative pulmonary complications (Dull and Dull 1983, Jenkins et al 1989, Stiller et al 1994). As a result of such findings, it is possible that physiotherapists may choose to use ambulation on its own in wider post-operative populations. The ability of post-operative ambulation to significantly increase tidal volume has not, to the authors’ knowledge, previously been investigated.
This study shows that tidal volume does not increase to a great extent during ambulation, particularly when compared with the effects of standing up alone, on tidal volume. Furthermore, the increase in tidal volume seen during ambulation is not nearly as large as that seen during deep breathing exercises.

One possible reason why greater increases in tidal volume may not be seen during ambulation concerns the post-operative patient's altered lung and chest wall mechanics. Following upper abdominal surgery, patients' lungs and chest wall are stiffer (Neely et al 1970), and it takes more energy for them to expand their lungs and chest wall. It has been proposed that in diseased states, patients will adopt the most energy-efficient pattern of breathing (McIlroy et al 1954). Therefore it is likely that in the post-operative period, patients will rely more on increasing respiratory rate in order to maintain their minute ventilation (Okinaka 1967). Similarly, during ambulation, it may be more energy-efficient for patients to increase their minute ventilation by increasing respiratory rate, rather than relying on larger increases in tidal volume. It is possible that larger increases in tidal volume would have been observed if patients were exercised at a higher intensity. In light of these factors, if one of the aims of post-operative ambulation is to achieve large increases in tidal volume, then patients should be encouraged to consciously augment their tidal volumes while they walk.

Although it is not possible to determine from the findings of the present study alone whether the ability of deep breathing exercises to achieve larger increases in tidal volume will translate into a greater ability to affect atelectasis and, importantly, gas exchange, there is evidence to suggest that this may be the case, at least in patients after upper abdominal surgery. Two studies performed in these patients found that deep breathing exercises were more effective than ambulation alone in the prevention of post-operative pulmonary complications (Celli et al 1984, Roukema et al 1988). Since the findings of the present study suggest that the main difference between the two treatments is in their effect on tidal volume, it may be that it is the ability of deep breathing exercises to achieve much larger increases in tidal volume, that is responsible for their greater effectiveness in preventing post-operative pulmonary complications.

Further evidence that supports the importance of increasing tidal volume is provided by the findings of a controlled study by Alexander et al (1981). This study compared the incidence of post-operative pulmonary complications (defined as abnormal roentgenographic findings) in groups of patients receiving either incentive spirometry under supervision or instruction only, incentive spirometry and intermittent positive pressure breathing, or no specific therapy (this group was encouraged to ambulate early and to breathe deeply). They found that although there was no significant difference in the incidence of post-operative pulmonary complications between the treatment groups, once patients were grouped according to the percentage of pre-operative maximal inspiratory volume they could achieve, those patients who achieved a greater percentage of their pre-operative maximal inspiratory volume during treatment had a reduced incidence of post-operative pulmonary complications.

In short, there is evidence to suggest that in upper abdominal surgery patients, the ability to increase tidal volume has an important role in the prevention of post-operative pulmonary complications. The finding of this study, that deep breathing exercises are able to achieve much larger increases in tidal volume than ambulation, therefore suggests that deep breathing exercises should be considered as an important technique that physiotherapists can use with patients after upper abdominal surgery.

The finding that inspiratory flow rate actually increased during deep breathing exercises, despite reductions in respiratory rate, challenges a commonly held belief about the effects of deep breathing exercises. It is commonly assumed that, because patients are instructed to breathe in slowly, and because respiratory rates decrease, inspiratory flow rates are also lower during deep breathing exercises. Tidal volume increased almost four-fold during the coached deep breaths, while respiratory rate decreased only by about one-third. The fact that patients breathe such large tidal volumes, even over a longer inspiratory time, means that inspiratory flow rates would be higher than during rest.

Finally, this study found that there were no clinically significant carry-over effects of either deep breathing exercises or ambulation on any parameter of pattern of breathing after treatment. Although some statistically significant carry-over effects on tidal volume and respiratory rate were seen after deep breathing exercises, the conclusion that there are no clinically significant carry-over effects is made because not all of the changes in pattern of breathing
seen at five and 30 minutes after treatment in this study can be attributed to the effects of the treatment. At five and 30 minutes after treatment, some patients chose to sit out of bed in a chair. Therefore some of the differences seen in pattern of breathing between rest, when patients were resting in bed, and at five and 30 minutes after treatment could be attributed to the different body position.

Minute ventilation, even five minutes after treatment, fell back close to resting level. It may have been that as a result of both treatments, gas exchange improved and thus the demand for ventilation decreased. There is certainly evidence to suggest that gas exchange improves after both deep breathing exercises (Bartlett et al 1970, Ravin 1966) and post-operative ambulation (Scheidegger et al 1976).

The finding that tidal volumes were not much higher after the deep breathing exercises than they were during rest, however, is more difficult to explain. Some carry-over effect in pattern of breathing is expected after deep breathing exercises, because deep breathing exercises have been shown to be effective in re-expanding collapsed alveoli (Ferris and Pollard 1960). This has the effect of increasing lung compliance and therefore patients should find it easier to breathe with a larger and more normal tidal volume. For this reason it is expected that following breathing exercises, patients will be breathing deeper and more slowly than they were before the treatment. In their study, Ferris and Pollard (1960) found that the beneficial effects of deep breathing exercises (in both normal subjects and patients with neuromuscular disease) lasted up to one hour, after which time lung compliance fell back to pre-treatment levels.

A possible reason as to why the present study failed to show any clinically significant carry-over effect of deep breathing exercises on pattern of breathing, even after five minutes, is the omission from this study of the inspiratory hold. Adding an inspiratory hold of at least three seconds is known to be more effective at re-expanding collapsed alveoli than deep breaths performed without a hold (Ward et al 1966), mainly because this allows more ventilation to be redistributed to less compliant alveoli (Menkes and Traysmian 1977). If inspiratory holds were added to the maximum inspirations in this study, a greater carry-over effect may have been seen.

The finding of a very small carry-over effect on tidal volume after deep breathing exercises may have important clinical implications. In order for deep breathing exercises to be effective in the management of post-operative atelectasis, they have to be performed regularly. It is known that alveoli have a natural tendency to collapse, and that in order to remain inflated, they need to be re-expanded regularly through the performance of deep breaths (Bendixen et al 1964, Ferris and Pollard 1960). The current prescription of hourly deep breathing exercises is based largely on the findings of previous studies (Ferris and Pollard 1960) that have found the effects of deep breathing exercises to last up to one hour. However, this study found that even five minutes after deep breathing exercises, tidal volumes fell back to close to resting level. Clearly, further research is needed to more fully determine the carry-over effects of deep breathing exercises. If indeed, as the results of the present study suggest, there are no significant carry-over effects after deep breathing exercises, the current hourly prescription of deep breathing exercises may need to be reviewed. It may be that, in order for deep breathing exercises to be more effective, patients need to perform deep breathing exercises more regularly than the current prescription of every hour.

**Conclusions**

It appears that post-operative patients are not being ambulated at a sufficient intensity in order to achieve significant increases in minute ventilation. If indeed this is an aim of the physiotherapist’s treatment, it is suggested that physiotherapists may need to take a more objective approach to the ambulation of post-operative patients. In addition, if one of the physiotherapist’s aims with ambulation is to effect significant increases in tidal volume, it is also suggested that physiotherapists encourage patients to take deep breaths during ambulation. The ability of deep breathing exercises to achieve much larger increases in tidal volume than ambulation suggests that deep breathing exercises should be considered as an important treatment technique that physiotherapists can offer patients after upper abdominal surgery. Finally, the finding of very little carry-over effects after deep breathing exercises warrants further investigation.

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References


