This study investigated the provision of additional evening physiotherapy on pulmonary complications and intrapulmonary shunt (Qs/Qt) after abdominal surgery. Thirty-one elderly patients received either daylight only or daylight plus evening physiotherapy for up to 48 hours. Physiotherapy included combinations of positioning, gravity-assisted drainage, breathing exercises, manual techniques, coughing and airway suctioning. Measurements included Qs/Qt and post-operative pulmonary complications. While no significant difference in atelectasis was found, the post-operative Qs/Qt data averaged into six-hour time frames demonstrated significantly lower mean Qs/Qt for the daylight plus evening physiotherapy group between 18 and 24 hours post-surgery. Additional evening physiotherapy may reduce post-operative deterioration in gas exchange after major abdominal surgery.


Key words: Intensive Care; Physical Therapy; Post-Operative Complications; Surgery

G Ntoumenopoulos BAppSc(Phy), BSc(Anat), PhD is Senior Clinician, Cardiorespiratory Physiotherapy, The Royal Melbourne Hospital. KM Greenwood BBSc(Hons), DipCompSc, PhD is a senior lecturer in the School of Behavioural Health Sciences, La Trobe University. Correspondence: Dr Ken Greenwood, School of Behavioural Health Sciences, Faculty of Health Sciences, La Trobe University, Victoria 3083.
to be at risk on the basis of increased American Association of Anesthesiologists (ASA) scale and age (Hall and Hall 1996) were studied, with patients alternately allocated to the daylight physiotherapy group \( (n = 15) \) and to the daylight plus evening physiotherapy group \( (n = 16) \). The patients studied were similar to the "at risk" group described and investigated by Older and Smith (1988). Baseline data demonstrated that the two physiotherapy groups did not differ significantly on a number of variables relevant to cardiopulmonary function (Table 1). The surgical procedures included repair of abdominal aortic aneurysms, colorectal surgery and other major vascular abdominal surgery, with no significant differences between the physiotherapy groups (Table 2).

**Table 1.** Comparison of pre-operative risk factors according to membership of the daylight or daylight plus evening physiotherapy groups.

<table>
<thead>
<tr>
<th>Pre-operative profile</th>
<th>Daylight ( n = 15 )</th>
<th>Daylight plus evening ( n = 16 )</th>
<th>Result of statistical comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age (range)</td>
<td>71 (53-83) years</td>
<td>72 (63-82) years</td>
<td>( t_{28} = -0.32, p &gt; 0.05 )</td>
</tr>
<tr>
<td>Smoker</td>
<td>11 patients</td>
<td>12 patients</td>
<td>( \chi^2_{(1)} = 0.11, p &gt; 0.05 )</td>
</tr>
<tr>
<td>Chronic airflow limitation</td>
<td>3 patients</td>
<td>7 patients</td>
<td>( \chi^2_{(1)} = 1.99, p &gt; 0.05 )</td>
</tr>
<tr>
<td>Cardiovascular dysfunction*</td>
<td>9 patients</td>
<td>13 patients</td>
<td>( \chi^2_{(1)} = 1.69, p &gt; 0.05 )</td>
</tr>
<tr>
<td>Pre-operative Cardiac Output [mean (SD)]</td>
<td>4.83 (1.30) L/min</td>
<td>5.36 (1.53) L/min</td>
<td>( t_{28} = 1.013, p &gt; 0.05 )</td>
</tr>
</tbody>
</table>

* includes either congestive cardiac failure, or ischaemic heart disease, or major heart rhythm disturbances, or combinations of these.

**Table 2.** Number of patients undergoing the various surgical procedures according to membership of the daylight or daylight plus evening physiotherapy groups.

<table>
<thead>
<tr>
<th>Surgical procedures</th>
<th>Daylight</th>
<th>Daylight plus evening</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abdominal</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>aortic aneurysm</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>Colorectal</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Gastric</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Other major</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

Measures

In this study, \( Q_s/Q_t \) was the main outcome measure. The incidence of pulmonary complications, assessed by chest radiograph, and the requirement for continuing mechanical ventilatory support, were also assessed. Shunt was measured immediately before and after cardiothoracic physiotherapy treatment (short-term effects) and also at regular intervals throughout the patient's post-operative stay in the ICU to determine whether the long-term effects were related to the short-term effects.

A pulmonary arterial and intraarterial catheter were inserted by medical staff 24h prior to the planned abdominal surgery, together with continuous electrocardiograph (ECG) monitoring. Baseline arterial and mixed venous blood were directly sampled by nursing staff and analysed by a blood gas analyser (Instrumentation Laboratories 1312) to enable the calculation of arterial (\( PaO_2 \)) and mixed venous (\( SvO_2 \)) partial pressure of oxygen, arterial (\( SaO_2 \)) and mixed venous (\( SvO_2 \)) saturation, and \( Q_s/Q_t \) using a modified version of the Berggrens equation (Older and Smith 1988).

\[
Q_s/Q_t = \frac{(CcO_2 - CaO_2)}{(CcO_2 - CvO_2)}
\]

where \( CcO_2 \) equals the oxygen content in end capillary blood; \( CaO_2 \) equals the oxygen content of systemic arterial blood; and \( CvO_2 \) equals the oxygen content of mixed venous blood. The direct measurement of \( CcO_2 \) is impossible, therefore the Ideal Alveolar Equation is used as it is assumed that the end capillary PO2 is equal to the Ideal Alveolar Oxygen. The \( CaO_2 \) and \( CvO_2 \) are calculated from the measurement of arterial and mixed venous saturation respectively (Older and Smith 1988). Shunt values are normally below 5 per cent (Older and Smith 1988).

The samples of arterial and mixed venous blood required for the calculation of \( Q_s/Q_t \) were always taken after the patient had been sitting upright for at least 20 minutes. Preoperative cardiac output, using the thermodilution method, was also determined by nursing staff (Older and Smith 1988). A portable erect anteroposterior chest radiograph was obtained 1-2h following the insertion of the pulmonary artery catheter. Prior
to surgery, the physiotherapist clinically evaluated the patient's respiratory system including the pattern of breathing, lung auscultation and cough adequacy and instructed the patient in the peri-operative physiotherapy regimens including hourly deep breathing, coughing and lower limb circulation exercises.

Cardiopulmonary function measurements, including $Q_s/Q_t$ and oxygenation (arterial and mixed venous) were determined and obtained by nursing staff as previously described, at least 1h before and immediately prior to physiotherapy and then at 20min and approximately 2h following each physiotherapy treatment (short-term outcome). In addition to the measurement of $Q_s/Q_t$, immediately before and after each session of physiotherapy, measurements were obtained at least every 4-6h whilst in the ICU (normally 48h) to evaluate long-term outcome.

A further portable anteroposterior chest radiograph (upright) was taken within 2 hours of the patient's return to the ICU from surgery to determine the post-operative pulmonary complications that may have developed immediately after surgery prior to the commencement of physiotherapy. The chest radiographs were also repeated at approximately 0600h each morning. One of three radiologists blind to the physiotherapy group allocation evaluated the radiographs regarding the film quality and the presence and severity of cardiopulmonary pathology. If the patients returned to the ICU intubated and mechanically ventilated, then the time on mechanical ventilatory support was recorded. It is acknowledged that radiographic and auscultatory findings may have limited reliability (Allingam et al 1995, Beydon et al 1997). However, these variables were included as they remain a routine part of clinical decision making by the physiotherapist in the majority of settings.

All tabular nominal data were analysed using Chi-square or Fisher's exact test (when appropriate). All two group comparisons with interval or ratio data were made with independent $t$ tests. Intrapulmonary shunt data were analysed with two factor split plot factorial ANOVA comparing the two groups over time with post hoc testing via simple main effects. For all analyses, $p < 0.05$ was considered significant.

Cardiopulmonary function

Cardiothoracic physiotherapy treatment protocols

Physiotherapy treatment after surgery incorporated a combination of techniques dependent on the evaluation findings, including deep breathing exercises (diaphragmatic, positioning, gravity assisted drainage with or without manual techniques (chest wall percussion and/or chest wall vibrations), coughing, airway suctioning and/or mobilisation of the patient out of bed.

With the presence of acute lung atelectasis/consolidation on the chest radiograph and/or added lung sounds on auscultation such as bronchial breathing/crackles, physiotherapy treatment included gravity assisted drainage, deep breathing exercises, manual techniques, coughing and/or airway suctioning. With the absence of major clinical signs as previously described, treatment included deep breathing exercises and coughing combined with positioning such as sitting upright, sitting out of bed or side-lying.

Once the patient was stabilised after surgery (body temperature > 36 degrees C, heart rate > 60 bpm and < 130 bpm without any compromising arrhythmia, mean arterial blood pressure > 70 mmHg < 120 mmHg, mean pulmonary arterial pressure < 30 mmHg, pulmonary capillary wedge pressure < 17 mmHg, calculated $\text{SaO}_2 > 90$ per cent and calculated $\text{SvO}_2 > 60$ per cent (from sampled arterial and mixed venous bloods, respectively), cardiothoracic physiotherapy was commenced. Cardiothoracic physiotherapy treatments were applied by the same physiotherapist (GN) to reduce the variability in the method of assessment and treatment application. The physiotherapist was blind to the measures of oxygenation and $Q_s/Q_t$ throughout the study, so these results were not considered in the treatment decision making process.

Daylight cardiothoracic physiotherapy involved the provision of two sessions of physiotherapy between 0830h and 1700h, once in the morning and once in the afternoon. Such procedures are considered standard practice in many Australian hospitals (N toumenopoulos and Greenwood 1991). Daylight plus evening physiotherapy also incorporated two sessions of therapy between 0830h and 1700h and at least one further session of therapy between 1700h and 2100h. These routines were continued for up to 48h after surgery. In between these physiotherapy treatments, nursing staff would encourage deep breathing and coughing hourly, perform airway suctioning and position patients from side to side two-hourly as required.

All patients in this study were those who would normally have been admitted to the ICU pre-operatively as a matter of policy of the Division of Anaesthesia and Intensive Care of Western Hospital in Melbourne. The peri-operative ICU procedures were explained to the patients by the medical staff and patient consent for the procedures was obtained. The director of the ICU deemed that as this study involved standard cardiothoracic physiotherapy treatment as already provided in this ICU, patient consent for the additional evening physiotherapy was not required. Ethical approval for the conduct of the study was obtained from the Western Hospital Ethics Board.

**Results**

Clinical management and assessment findings

All patients were transferred directly from theatre to the ICU. Some patients were left intubated and others were extubated in theatre. Approximately 50 per cent of the patients returned to the ICU...
intubated, with no significant differences between the physiotherapy groups. During the majority of physiotherapy treatments (83 per cent), patients were non-intubated. Patients were receiving some form of inotropic support, including dopamine, dobutamine and/or glyceryl trinitrate (GTN) during 79 per cent of physiotherapy treatments. The method of analgesic management included the administration of narcotics via the intravenous route (22 per cent), epidural route (52 per cent), or combination of both (26 per cent), with no significant differences between the two physiotherapy groups. Decreased and adventitious lung sounds were often auscultated by the physiotherapist before treatment. Diminished breath sounds, crackles and bronchial breathing were noted prior to 97 per cent, 59 per cent and 21 percent of treatment sessions respectively. There were no major differences between the two physiotherapy groups on any of these findings.

Specific physiotherapy treatment procedures used

Physiotherapy techniques predominantly included positioning (gravity assisted drainage, side-lying and sitting out of bed), deep breathing exercises (Stiller and Munday 1992), coughing and airway suctioning (endotracheal or nasopharyngeal). Details of the techniques used are provided in Table 3. No significant differences were found between the physiotherapy groups on any of these treatment variables. Mean (SD) duration of physiotherapy assessment and treatment was 41 (10) minutes with no differences between the physiotherapy groups.

The daylight plus evening physiotherapy group did, of course, receive significantly more physiotherapy treatments than the daylight physiotherapy group (5.3 [0.7] vs 3.1 [0.9] treatments respectively). Treatment also commenced significantly sooner after surgery in the daylight plus evening physiotherapy group (3.4 [1.4] hours) compared with the daylight physiotherapy group (8.4 [8.6] hours). This resulted because physiotherapy treatment commenced for all the patients in the daylight plus evening physiotherapy group on the evening of surgery, whereas some patients \( (n = 5) \) in the daylight physiotherapy group, due to the timing of their return from surgery (late afternoon or evening), did not receive physiotherapy treatment until the first post-operative day.

Post-operative pulmonary complications

Acute atelectasis, verified radiologically, developed in 16/31 patients (51 per cent) with no significant differences between the two physiotherapy groups. Patients from the daylight physiotherapy group who returned to the ICU intubated and mechanically ventilated, remained intubated for (mean [SD]) 18.10 [12.90] hours, compared with only 9.40 [17.90] hours for the daylight plus evening physiotherapy group, but the difference was not significant \( t_{(13)} = 1.10, p = 0.29 \).

Investigation of short-term effects of cardiothoracic physiotherapy

A total of 132 treatments were applied to the 31 patients after surgery, with 85 treatments applied to the daylight plus evening physiotherapy group and 47 treatments applied to the daylight physiotherapy group. There were no significant changes in \( Q_s/Q_t \) immediately after physiotherapy. The mean (SD) pre-treatment \( Q_s/Q_t \) was 17.3 (7.4) per cent which did not differ significantly from the post-treatment value of 16.9 (6.8) per cent.

Long-term changes in \( Q_s/Q_t \)

Mean (SE) \( Q_s/Q_t \) values during the 6h time periods following surgery are presented in Figure 1 for both groups. The groups had similar pre-operative \( Q_s/Q_t \) values of approximately 10 per cent. In the first six hours after surgery, \( Q_s/Q_t \) was increased to around 15 per cent for both groups, again without major differences between the two groups. After this time, the values for the daylight group exceeded those seen in the daylight plus evening
Austalian Physiotherapy Group. The values beyond 42h should be viewed with some caution, as a large number of patients had left the ICU by this stage and these values were obtained from more seriously ill patients.

To analyse the averaged Qs/Qt data by two factor ANOVA comparing the two treatment groups (daylight versus daylight plus evening) over the nine 6h time periods, complete data sets for each subject over the repeated measures are required. The most complete data sets for this analysis were available only up to 36h after surgery, with 16/16 patients from the daylight plus evening physiotherapy group and 13/15 patients from the daylight physiotherapy group included. At 42h, only 12 daylight and 15 daylight plus evening patients remained. At 48h the numbers remaining in the ICU were nine and 15 respectively and at 54h only five remained in each group.

The two factor ANOVA comparing the average Qs/Qt data in six hour time frames across the 36h post-operative period resulted in a significant main effect for time ($F(6,162) = 19.15$, $p < 0.001$) and a significant group by time interaction ($F(6,162) = 2.33$, $p < 0.05$). Post hoc tests, using simple main effects, found no differences in Qs/Qt before surgery and for each 6h time period up to 18 hours after surgery in both physiotherapy groups (Table 4). However, between 18 and 24 hours after surgery, significantly lower Qs/Qt was displayed in the daylight plus evening physiotherapy group compared with the daylight physiotherapy group (Table 4). Beyond this time frame, differences of important clinical magnitude were found but they failed to reach statistical significance.

**Table 3.** Percentage of treatment sessions in which various cardiothoracic physiotherapy techniques were used by the physiotherapist for all treatment sessions, for the daylight physiotherapy group and for the daylight plus evening physiotherapy group.

<table>
<thead>
<tr>
<th>Treatment description</th>
<th>All treatments</th>
<th>Daylight</th>
<th>Daylight plus evening</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nasopharyngeal suction (115 treatments)</td>
<td>38</td>
<td>27</td>
<td>43</td>
</tr>
<tr>
<td>Manual chest percussion (132 treatments)</td>
<td>23</td>
<td>30</td>
<td>19</td>
</tr>
<tr>
<td>Vibrations (132 treatments)</td>
<td>32</td>
<td>38</td>
<td>28</td>
</tr>
<tr>
<td>Deep breathing exercises (115 treatments)</td>
<td>70</td>
<td>85</td>
<td>65</td>
</tr>
<tr>
<td>Cough (115 treatments)</td>
<td>64</td>
<td>65</td>
<td>63</td>
</tr>
<tr>
<td>Gravity assisted drainage (132 treatments)</td>
<td>46</td>
<td>46</td>
<td>46</td>
</tr>
<tr>
<td>Sidelying (132 treatments)</td>
<td>29</td>
<td>30</td>
<td>28</td>
</tr>
<tr>
<td>Sitting up-right (132 treatments)</td>
<td>10</td>
<td>9</td>
<td>12</td>
</tr>
<tr>
<td>Sitting out of bed (132 treatments)</td>
<td>14</td>
<td>15</td>
<td>14</td>
</tr>
</tbody>
</table>

**Table 4.** Mean (SD) Qs/Qt (%) for the physiotherapy groups averaged into six-hour time frames across the 36h post-operative period and results of post-hoc tests.

<table>
<thead>
<tr>
<th>Time following surgery</th>
<th>Daylight $n = 13$</th>
<th>Daylight plus evening $n = 16$</th>
<th>Post-hoc tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-surgery</td>
<td>9.93 (5.41)</td>
<td>10.92 (5.24)</td>
<td>NS *</td>
</tr>
<tr>
<td>0 - 6 hours</td>
<td>15.03 (7.24)</td>
<td>14.36 (6.93)</td>
<td>NS</td>
</tr>
<tr>
<td>6 - 12 hours</td>
<td>16.33 (6.50)</td>
<td>14.96 (6.80)</td>
<td>NS</td>
</tr>
<tr>
<td>12 - 18 hours</td>
<td>17.68 (4.64)</td>
<td>16.85 (6.05)</td>
<td>NS</td>
</tr>
<tr>
<td>18 - 24 hours</td>
<td>22.00 (9.74)</td>
<td>16.97 (5.27)</td>
<td>$p &lt; 0.05$</td>
</tr>
<tr>
<td>24 - 30 hours</td>
<td>19.60 (7.64)</td>
<td>17.19 (6.00)</td>
<td>NS</td>
</tr>
<tr>
<td>30 - 36 hours</td>
<td>20.85 (6.67)</td>
<td>16.31 (5.23)</td>
<td>$p &lt; 0.1$</td>
</tr>
</tbody>
</table>

*NS = not significant

Discussion

This study provides some evidence that the provision of additional evening cardiothoracic physiotherapy as described in this study may assist in lowering Qs/Qt in the elderly abdominal surgical patient. The physiotherapy groups did not differ significantly on relevant measures of cardiopulmonary function prior to or immediately after surgery, which provides some support for the inference that the additional cardiothoracic physiotherapy was responsible for the differences in Qs/Qt observed. However, the study has several limitations, including the small numbers of patients investigated (which may have reduced power) and the use of multiple physiotherapy techniques. In addition, the daylight plus evening physiotherapy group contained a slightly greater proportion (not statistically significant) of lower abdominal surgery patients in which has been previously reported to be associated with a lower incidence of post-operative pulmonary
From Page 301

complications (Castillo and Haas 1985).

The statistically significant differences in Qs/Qt observed emerged between 18 and 24 hours post-surgery, and while significant only during that time period, appeared to persist for the remainder of the 48h observation period. Whether the magnitude of the differences in Qs/Qt between the two physiotherapy groups affected mortality and morbidity (eg length of stay), should be further investigated with greater patient numbers (Shoemaker et al 1988).

The additional physiotherapy failed to lower the incidence of acute atelectasis. However, considering the poor sensitivity of the portable chest radiograph in detecting atelectasis (Beydon et al 1992), a limited emphasis should be placed on these findings. A trend in the data indicated a reduced requirement for mechanical ventilatory support in the daylight plus evening physiotherapy group. This may have been due to the earlier start of cardiothoracic physiotherapy treatment after surgery and the increased frequency of cardiothoracic physiotherapy treatment over the early post-operative period.

It is not clear from this study exactly what aspect of the additional cardiothoracic physiotherapy received by the daylight plus evening group may have been responsible for the improved Qs/Qt. It could be associated with the increased number of physiotherapy sessions received by this group. Alternatively, it could be a function of the extension of treatment into the evening hours rather than being associated solely with increased treatment sessions. A final potential explanation is that the improved outcome in the group was due to less time elapsing between surgery and the first treatment session. A different study would be required to separate these alternative explanations.

Improvement in Qs/Qt after similar cardiothoracic physiotherapy regimens as used in the present study has been demonstrated by Mackenzie and Shin (1985) in young multi-trauma patients. In addition, increased clearance of airway secretions (Hammon 1983), improved total lung/thorax compliance (Jones et al 1992, Mackenzie and Shin 1985) and arterial oxygenation (Stiller et al 1990) after physiotherapy has also been demonstrated in a variety of trauma, surgical and medical patients.

However, some studies have also reported adverse short-term effects associated with cardiothoracic physiotherapy, including increased or decreased cardiac output (Laws and McIntyre 1969), reductions in arterial oxygenation (Conners et al 1980, Tyler et al 1980) and mixed venous oxygenation (Barrell and Abbas 1978). Possible causes of these adverse responses include ventilation and perfusion mismatching with change of position, in addition to arterial and mixed venous desaturation with the increased metabolic demands of the physiotherapy procedures (Aitkenhead et al 1984, Glauser et al 1988, Klein et al 1988, Weissmann et al 1984). Pharmacologic therapy may be used to alleviate some of the increased metabolic and haemodynamic demands of cardiothoracic physiotherapy treatment (Klein et al 1988). The present study overall did not find any adverse short-term changes in cardiopulmonary function as assessed by Qs/Qt. Even if these occurred, it seems that over the long term, the cardiothoracic physiotherapy techniques applied in this study had no detrimental effects on the patients studied.

Conclusion

This study provides some evidence suggesting that additional evening cardiothoracic physiotherapy after major abdominal surgery may lower the post-operative deterioration in gaseous exchange as indicated by Qs/Qt in elderly at risk patients. However, it is unclear which techniques of physiotherapy, if any, were beneficial. Further investigation with larger patient numbers is warranted.

Acknowledgments

The authors gratefully acknowledge the support and assistance of Dr Paul Older, Director of Critical Care, and the nursing staff at the Western Hospital Critical Care Unit, without whom this study could not have been undertaken. In addition, we would like to thank Dr Jim French and the Radiology Department for the evaluations of the chest radiographs and the Physiotherapy Department for their valued support and dedication to this study.

References


Conners AF, Hammon WE, Martin RJ and Rogers RM (1980): Chest physical therapy. The immediate effect on oxygenation in acutely ill patients. *Chest* 78: 559-564.


