

Narrative review

Incentive spirometry following thoracic surgery: what should we be doing?

Paula Agostini^{a,*}, Sally Singh^b

^a *Physiotherapy Department, Heartlands Hospital, Bordesley Green East, Bordesley Green, Birmingham B9 5SS, UK*

^b *School of Health and Life Sciences, Coventry University, Priory Street, Coventry CV1 5FB, UK*

Abstract

Background Thoracic surgery may cause reduced respiratory function and pulmonary complications, with associated increased risk of mortality. Postoperative physiotherapy aims to reverse atelectasis and secretion retention, and may include incentive spirometry.

Objectives To review the evidence for incentive spirometry, examining the physiological basis, equipment and its use following thoracic surgery.

Data sources MEDLINE was searched from 1950 to January 2008, EMBASE was searched from 1980 to January 2008, and CINAHL was searched from 1982 to January 2008, all using the OVID interface. The search term was: '[incentive spirometry.mp]'. The Cochrane Library was searched using the terms 'incentive spirometry' and 'postoperative physiotherapy'. The Chartered Society of Physiotherapy Resource Centre was also searched, and a hand search was performed to follow-up references from the retrieved studies.

Review method Non-scientific papers were excluded, as were papers that did not relate to thoracic surgery or the postoperative treatment of patients with incentive spirometry.

Results Initially, 106 studies were found in MEDLINE, 99 in EMBASE and 42 in CINAHL. Eight references were found in the Cochrane Library and one paper in the Chartered Society of Physiotherapy Resource Centre. Four studies and one systematic review investigating the effects of postoperative physiotherapy and incentive spirometry in thoracic surgery patients were selected and reviewed.

Conclusion Physiological evidence suggests that incentive spirometry may be appropriate for lung re-expansion following major thoracic surgery. Based on sparse literature, postoperative physiotherapy regimes with, or without, the use of incentive spirometry appear to be effective following thoracic surgery compared with no physiotherapy input.

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Keywords: Postoperative physical therapy; Incentive spirometry; Thoracic surgery

Introduction

Thoracic surgery may cause reduced respiratory function and pulmonary complications, with associated increased risk of mortality. The risk of postoperative pulmonary complications is relatively high following thoracic surgery; rates have been recorded at between 19% and 59%, compared with only 16% and 17% for upper abdominal surgery and 0% and 5% for lower abdominal surgery [1]. Large variation in the recorded rate of postoperative pulmonary complications may reflect the use of multiple definitions and criteria. Postoperative physiotherapy aims to reverse atelectasis and secretion retention, and may include deep breathing exercises, posi-

tioning, airway clearance techniques and mobilisation. Intermittent, deep, prolonged inspiratory efforts are thought to re-inflate collapsed alveoli, increase pulmonary compliance and reduce regional ventilation–perfusion inequalities [2]. Incentive spirometry involves deep breathing through a device with visual feedback, thought to maximise accuracy of breathing technique and motivation [3]. It is recommended following non-cardiothoracic surgery by the American College of Physicians [4]; however, systematic reviews of the evidence for physiotherapy, including incentive spirometry, following cardiac or abdominal surgery [5–8] show little or no evidence of benefit, although the papers reviewed often demonstrate incomparable outcome measures and methodological inadequacy. A review of the physiological basis for incentive spirometry, the equipment and the evidence for its use following thoracic surgery has not been published previously.

* Corresponding author. Tel.: +44 121 424 2000; fax: +44 121 424 1064.
E-mail address: paula.agostini@heartofengland.nhs.uk (P. Agostini).

Due to the large variation in postoperative practice, increased risk of complications following thoracic surgery, and the fact that incentive spirometry may be an important adjunct to physiotherapy, a comprehensive review of this area is needed.

Background information

Major thoracic surgical procedures, such as thoracotomy, may lead to severe depression of pulmonary function through atelectasis, secretion retention, altered chest wall mechanics and abnormal breathing pattern [9]. The causes of postoperative atelectasis are regional hypoventilation and airway closure. Hypoventilation occurs in the dependent areas of the lung compressed through the effects of supine positioning with concurrent respiratory muscle paralysis [10] and positive pressure ventilation [11]. This is further exacerbated by the absorption of highly diffusible anaesthetic gases and oxygen. During thoracic surgery, which necessitates lateral positioning, the dependent lung is more vulnerable to the effects of compression and absorption, and up to double the resting lung volume (functional residual capacity) may be lost compared with that of the lung in a supine subject [12].

In the immediate postoperative period, a combination of drowsiness, pain and analgesia may lead to a slow, monotonous, shallow breathing pattern [13], recumbent positioning and decreased mobility, leading to further regional hypoventilation. Depth of respiration in thoracic surgery patients may also be impaired by chest wall incisions and insertion of intercostal chest drains. Airway narrowing may be exacerbated in this period by dysfunctional mucociliary clearance, together with painful cough, causing secretion retention.

As the functional residual capacity decreases, tidal breathing occurs in the range of closing capacity, leading to further collapse of dependent airways [9]. Loss of tissue compliance ensues with an associated shallow, rapid breathing pattern which impairs ventilation and capacity to cough still further. Unless these problems are reversed, atelectasis, or collapse, will progress in a self-perpetuating cycle. Thoracic surgery patients may be at increased risk because, as a group, they are older and may have existing cardiopulmonary disease associated with a history of smoking.

Physiological basis of incentive spirometry

Treatment of reduced postoperative pulmonary function

The principles of atelectasis management are simple; remove retained secretions from the airway, and provide sufficient stretch to the lung tissue for the purpose of parenchymal re-expansion [14]. The 'ideal' deep breathing manoeuvre for recruiting collapsed alveoli was originally described by Bartlett *et al.* in 1973 [3]. They found that a large inflating volume and transpulmonary pressure gradient needed to be

maintained for several seconds in order to achieve lung re-expansion, possibly because obstructed areas take longer to fill. According to Bendixen *et al.* [15], who studied the normal pattern of ventilation in young adults, this should be carried out 10 times every hour to maintain lung inflation.

In order to fulfill the physiological requirements of re-expansion, breathing exercises should be characterised by a long, slow inspiration, with inspiratory hold where possible. Incentive spirometry offers these components and the additional benefit of visual feedback, giving the patient a measurable goal and encouraging good technique [3].

Incentive spirometry equipment

Many different incentive spirometers are available in the UK. Incentive spirometry devices can give visual feedback in terms of flow, volume or both. Flow-oriented devices require the patient to lift a marker to a certain point for a maximal amount of time, for example Mediflo Duo (Medimex, Hamburg, Germany) (Fig. 1) and Mediciser (Eastern Medikit Ltd., Gurgaon, India) (Fig. 2). Volume-oriented devices have a visible scale measuring inspiratory capacity on which the patient lifts a marker as high as possible. Devices known as volume accumulators have markers for volume and flow, for example the Coach 2 device (MediMark Europe, Grenoble, France) (Fig. 3) and the Spiroball (Leventon, Barcelona, Spain) (Fig. 4). These devices may be more appropriate following surgery as both flow and volume are important physiologically for lung re-expansion [3].

Work of breathing imposed by differing incentive spirometry devices has been explored. Mang and Obermayer [16] tested six different incentive spirometers in laboratory conditions. The two adult volume accumulator devices tested (Coach 2 and Voldyne 5000) imposed approximately half the work of breathing of the flow-orientated devices tested (Tri-



Fig. 1. Mediflo Duo device.



Fig. 2. Mediciser device.

flo and Lung Volume Exerciser). Ho *et al.* [17] examined the use of incentive spirometry in chronic obstructive pulmonary disease (COPD) patients, and also found improved volumes and less imposed work of breathing with the Coach device compared with the Triflo device. The study also demonstrated that 77% of the patients ($n=22$) tested preferred a volume-orientated device. Weindler and Kiefer [18] tested levels of imposed work of breathing on upper abdominal and thoracic surgery patients ($n=30$) using the Coach and Mediflo devices. They found that the Mediflo device imposed twice the amount of work of breathing, and concluded that the Coach device was more suitable postoperatively.

Parreira *et al.* [19] examined differences in tidal volume and thoraco–abdominal motion when using volume- and flow-orientated devices (Voldyne and Triflo). Sixteen healthy subjects were tested, and abdominal motion was found to be significantly greater during the use



Fig. 3. Coach 2 device.



Fig. 4. Spiroball device.

of volume-orientated devices, with increased tidal volumes, whilst increased ribcage activity was seen with flow-orientated incentive spirometry. In a similar study [20], 17 healthy subjects were compared performing deep breathing exercises, volume orientated incentive spirometry, and flow-orientated incentive spirometry (Voldyne and Triflo devices). Again, flow-orientated incentive spirometry demonstrated increased muscular activity in the upper chest, with little difference demonstrated in deep breathing exercises and volume-orientated incentive spirometry. Melendez *et al.* [21] investigated mechanical abnormalities following thoracotomy on 16 subjects. During volume-orientated incentive spirometry, they found that the diaphragm functioned more effectively in an upright position, but incentive spirometry did not generally encourage diaphragmatic breathing in comparison with deep breathing exercises.

Physiologically, there may be a difference in the effect of various devices. Volume-orientated devices appear to give improved diaphragmatic activity and decreased work of breathing compared with flow-orientated devices. More evidence to clarify differences in volume-orientated incentive spirometry and deep breathing exercises is needed. If using incentive spirometry postoperatively, volume-orientated devices are probably more suitable as there may be lower levels of imposed work of breathing, pain and fatigue, and subjects are more likely to achieve their best potential volume [19]. A volume-orientated device, the Coach 2, has also been demonstrated to be a reliable indicator of postoperative recovery following lobectomy [22].

Evidence base for incentive spirometry following thoracic surgery

A literature search was undertaken to find studies that investigated the effects of physiotherapy, including incen-

Table 1
Summary of selected papers.

Author, date and country	Patient group	Study type, level of evidence	Outcomes	Key results
Overend (2001) [5], Canada	A review of 46 studies looking at incentive spirometry to prevent postoperative pulmonary complications	Systematic review		35 of the 46 studies were rejected due to flaws in their methodology. 10 of the remaining 11 studies showed no benefit following cardiac or abdominal surgery. One study showed that incentive spirometry, deep breathing and positive pressure breathing reduced pulmonary complications equally
Varela (2006) [24], Spain	639 lobectomy patients (muscle-sparing thoracotomy or video-assisted thoracoscopy). Comparison of intensive physiotherapy with incentive spirometry alone (control)	Cross-sectional study with historical control	Pneumonia, atelectasis, length of hospital stay, mortality	Intense physiotherapy vs incentive spirometry alone. Atelectasis: 2 vs 8%, odds ratio 0.2, confidence interval 0.05 to 0.86. Length of hospital stay: 5.73 (2 to 22) vs 8.33 (3 to 40) days, $P < 0.001$
Gosselink (2000) [23], Belgium	67 thoracic surgery patients (40 lung/27 oesophageal resection). Comparison of postoperative chest physiotherapy vs postoperative chest physiotherapy with incentive spirometry	Randomised controlled trial	FEV ₁ recovery, postoperative pulmonary complications, length of hospital stay	Physiotherapy vs physiotherapy + incentive spirometry (no significant difference). % recovery of FEV ₁ : 88 ± 44 vs 72 ± 17 Length of hospital stay: 15 ± 7 vs 14 ± 8 days Postoperative pulmonary complications: 4/35 vs 4/32
Weiner (1997) [26], Israel	32 lung resection patients with chronic obstructive pulmonary disease (lobectomy/pneumonectomy). Comparison of incentive spirometry and inspiratory muscle training before and after surgery with no treatment	Randomised controlled trial	Predicted postoperative FEV ₁ , postoperative pulmonary complications	Incentive spirometry and inspiratory muscle training vs no treatment. Postoperative pulmonary complications: 2/17 vs 2/15. Value above predicted postoperative FEV ₁ : lobectomy +570 vs -70 ml, pneumonectomy +680 vs -110 ml at 3 months
Vilaplana (1991) [27], Spain	37 thoracic surgery patients (21 lung and 16 oesophageal surgery). Comparison of postoperative chest physiotherapy vs chest physiotherapy with incentive spirometry	Randomised controlled trial	Chest X-ray, auscultation, postoperative pulmonary complications, length of hospital stay, mortality, FEV ₁	Physiotherapy vs physiotherapy + incentive spirometry. Postoperative pulmonary complications: 4/19 vs 6/18. Length of hospital stay: 30.5 ± 16 vs 23.8 ± 11 days. % drop in FEV ₁ : oesophageal 49 vs 51, lung 45 vs 50

FEV₁, forced expiratory volume in 1 second.

tive spirometry, following thoracic surgery. MEDLINE was searched from 1950 to January 2008, EMBASE was searched from 1980 to January 2008, and CINAHL was searched from 1982 to January 2008, all using the OVID interface. The search term was: '[incentive spirometry.mp]'. The Cochrane Library was searched using the terms 'incentive spirometry' and 'postoperative physiotherapy'. The Chartered Society of Physiotherapy Resource Centre was also searched, and a hand search was performed to follow-up references from

the retrieved studies. Non-scientific papers were excluded, as were papers that did not relate to thoracic surgery or the postoperative treatment of patients with incentive spirometry. Initially, 106 studies were found in MEDLINE, 99 in EMBASE and 42 in CINAHL. Eight references were found in the Cochrane Library and one paper in the Chartered Society of Physiotherapy Resource Centre. Four studies and one systematic review investigating the effects of postoperative physiotherapy and incentive spirometry in thoracic surgery

patients were selected and reviewed; the methods and results are summarised in Table 1.

Overend *et al.* [5] performed the only systematic review to exclusively examine the effects of incentive spirometry, rather than physiotherapy in general, on postoperative pulmonary complications following cardiac, upper abdominal and thoracic surgery. The studies by Gosselink *et al.* [23] and Melendez *et al.* [21] were the only studies to include incentive spirometry following thoracic surgery. However, due to methodological inadequacy, the authors were unable to comment on the effect of incentive spirometry following thoracic surgery. Eleven articles were reviewed in total; the authors concluded that the evidence did not support the use of incentive spirometry following cardiac or abdominal surgery, and recommended that it should not be used. However, this was based on relatively few studies with contradictory results. Recommendations for further studies following thoracic surgery were made, as postoperative complication rates are higher compared with those of cardiac or abdominal surgery.

The most recent study by Varela *et al.* in 2006 [24] used a cross-sectional design with historical controls (non-randomised) to evaluate the cost-effectiveness of chest physiotherapy following lobectomy (via muscle sparing and video-assisted mini-thoracotomy). One hundred and nineteen subjects received intensive chest physiotherapy, specifically receiving instruction in deep inspiratory manoeuvres and cough; they also exercised using a static bicycle and treadmill. There is no further clarification of the deep inspiratory manoeuvres taught. Subjects were compared with a group of 520 similar subjects previously treated at the same hospital who had received routine nursing care and incentive spirometry. Device type is not specified in the paper, but is described as imposing a low work of breathing by Weindler and Kiefer [18] and therefore must be the volume-orientated Coach device. In this study, incentive spirometry was not compared as a physiotherapy treatment, but was used independently by patients instead of physiotherapy. Selected outcomes included length of stay, 30-day mortality and respiratory morbidity, including atelectasis and nosocomial pneumonia as defined by the American Thoracic Society [25].

The analysis showed that the overall cost of hospital treatment for the physiotherapy group was lower. There was no statistically significant difference in mortality rate, and although the prevalence of nosocomial pneumonia was lower in the physiotherapy group, there was no statistically significant difference. Nosocomial pneumonia as described by the American Thoracic Society [25] is classified in terms of mild, moderate and severe disease. The latter appears to be the only type with clearly defined criteria: admission to the intensive care unit, respiratory failure defined as the need for mechanical ventilation, rapid radiographic progression, and evidence of severe sepsis with hypotension and end-organ dysfunction. It is unclear which classification was of interest in the Varela trial, but with the rates of nosocomial pneumonia recorded (5% vs 9%), it is likely that this reflects

multiple types of nosocomial pneumonia rather than severe cases exclusively. It is therefore difficult to compare rates of postoperative pulmonary complications with other similar studies. The incidence of atelectasis was also lower in the physiotherapy group (2% vs 8%), demonstrating a statistically significant difference.

Length of stay was lower in the physiotherapy group (5.73 vs 8.33 days), demonstrating a statistically significant difference; however, data from the control group were collected over several years before the physiotherapy group, and practice affecting length of stay in this unit may have changed over time. In addition, many other unrelated factors are known to influence length of stay, and it should be noted that there were more video-assisted procedures in the physiotherapy group.

The design of this study was neither randomised nor blinded. The authors, however, emphasise that all perioperative practices remained unchanged in the experimental group, decreasing the relevance of design deficiencies. Compliance with treatment in the control group is unknown, as is their ability to perform incentive spirometry and compliance with instruction. It is therefore difficult to determine exactly what has been compared.

Gosselink *et al.* [23] performed a randomised controlled trial on subjects following lung ($n=40$) and oesophageal ($n=27$) surgery; selection was based upon the subject's ability to perform incentive spirometry adequately before surgery. These subjects were randomised to two groups; postoperative physiotherapy comprising deep breathing exercises, huff and cough ($n=35$), and volume-orientated incentive spirometry (Voldyne), huff and cough ($n=32$). Outcome measures included forced expiratory volume in 1 second (FEV₁), performed pre-operatively and up to 3 weeks postoperatively, length of stay and rate of postoperative pulmonary complications; no statistically significant differences between groups were identified.

The rate of postoperative pulmonary complications was relatively low, which, as acknowledged by the authors, probably indicates that the study was underpowered. The criteria to define complications were raised white cell count ($>12 \times 10^9/l$) or positive microbiology, increased temperature ($>38^\circ\text{C}$) and major unilateral or bilateral chest X-ray changes. A difficulty with this score is the subjectivity of the chest X-ray score, which could only be positive in the presence of 'major' changes. Reliance on raised temperature may lead to false-negative results, given that many postoperative patients receive analgesia which may suppress this increase. For length of stay, a difference of 1 day was considered important; however, a length of stay of 1 day can easily be affected by unrelated events. In order to detect such a small difference, it would be necessary to have over 600 subjects per group, as calculated by the authors following data collection.

Weiner *et al.* [26] performed a randomised controlled trial concerning the effect of incentive spirometry and inspiratory muscle training on predicted postoperative pulmonary function following lung resection. Thirty-two subjects with COPD were randomised; one group received physiotherapy

input consisting of volume-orientated incentive spirometry (Coach device) with inspiratory muscle training 2 weeks pre-operatively and for 3 months postoperatively ($n = 17$), and the other group received no specific training ($n = 15$). Outcomes were measured in terms of actual and predicted postoperative lung function, and inspiratory muscle strength. Inspiratory muscle strength increased significantly following 2 weeks of pre-operative training in the treatment group, and also at 3 months postoperatively. This group also had higher actual FEV₁ and forced vital capacity readings than the control group postoperatively, with no difference in the proportion of lung tissue removed from either group. The treatment group also demonstrated significantly higher FEV₁ and forced vital capacity than predicted at 3 months postoperatively, whereas the control group did not. This paper correctly used predicted postoperative FEV₁ to take the number of segments resected into account.

It is uncertain how much of this improvement in FEV₁ can be attributed to the volume effect of incentive spirometry or the 'loading' effect of inspiratory muscle training. However, in many of the postoperative regimens studied, and in clinical practice, several treatments are applied simultaneously. The authors did note that there were two cases of postoperative pneumonia in each group. No criteria or definition of pneumonia is documented, making comparison with other studies difficult.

Vilaplana *et al.* [27] performed a small ($n = 37$) randomised trial to assess the efficacy of routine incentive spirometry following thoracic surgery. They examined subjects who had undergone thoracotomy for oesophageal ($n = 16$) or pulmonary ($n = 21$) surgery. Group 1 received incentive spirometry (flow orientated), which was performed for 5 minutes every hour from 24 hours pre-operatively through to the postoperative period ($n = 18$). Group 2 received routine chest physiotherapy alone ($n = 19$), which included abdominal and costal deep breathing exercises, patient information including advice regarding changing position, and supported coughing. Outcome measures included chest X-ray changes, auscultation, postoperative complications, recovery of lung function, difference in postoperative gas exchange, length of stay and mortality. The results found that there was no statistically significant difference in FEV₁ after 48 hours of treatment, chest X-ray, postoperative gas exchange (arterial–alveolar O₂ difference), postoperative complications, length of stay or mortality.

This was a relatively small trial and may be underpowered. The use of a flow-orientated device (Triflo) may be less appropriate for these patients given the increased work of breathing and upper chest motion associated with this device. Postoperative complications included non-pulmonary pathology such as arrhythmias, angina and deep vein thrombosis, as well as pneumonia (undefined), making comparison between studies difficult for this outcome. Again, chest X-ray interpretation and auscultation is subjective, with length of stay possibly affected by external factors.

Conclusion

The literature suggests that several treatments commonly used by physiotherapists postoperatively, including incentive spirometry, may be appropriate in fulfilling the physiological requirements of lung re-expansion. Physiologically, there may be some advantages in using volume-orientated incentive spirometry, such as improved diaphragmatic activity and decreased work of breathing compared with flow devices. More evidence to clarify differences in volume-orientated incentive spirometry and deep breathing exercises is needed.

There is currently little evidence of benefit of incentive spirometry following major thoracic surgery; comparative studies are small in number and outcome measures are incomparable. Based on the sparse literature presented, postoperative physiotherapy regimes with, or without, the use of incentive spirometry appear to be effective following thoracic surgery compared with no physiotherapy input. The decision to use incentive spirometry following thoracic surgery should be made by individual physiotherapists based upon assessment, experience, training, resources and possibly preferences. To confirm treatment benefit, adequately powered studies are required. It would be appropriate to examine the effects of incentive spirometry within a postoperative treatment regimen as a whole, as this reflects usual clinical practice, with appropriate and well-defined outcome measures.

Conflicts of interest: None.

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