

Pre-operative physiotherapy for anaesthetised children with cystic fibrosis: A pilot study to assess the immediate and longer-term effects on respiratory function.

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This project was granted approval by the Institute of Child Health and Great Ormond Street Hospital for Children National Health Service (NHS) Trust Research and Ethics committee and written, informed consent was obtained from parents or patients who were recruited into the study

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Abstract

Background: Patients with cystic fibrosis (CF) undergoing elective surgical procedures usually require a general anaesthetic. Chest physiotherapy is often performed on these patients in theatre immediately prior to surgery following induction and intubation. This pilot study **aimed** to evaluate the effects of physiotherapy in the acute intra-operative period and its effect on the post-operative course in terms of lung function and physiotherapy requirement.

Methods: Patients were randomised either to receive physiotherapy or no intervention (control group) following induction of anaesthesia and intubation. Lung function (on the ward) and respiratory mechanics (under anaesthesia) were measured using the Jaeger Masterscreen and 'CO₂SMO Plus' respiratory monitor respectively.

Results: Eighteen patients, mean age 12 years (range 2.8-15 yrs) and mean forced expiratory volume in 1 second (FEV₁) 66.8% (range 54.0-81.0%) were recruited to the study. In eight patients receiving physiotherapy, the mean respiratory compliance (C_{rs}) was reduced significantly from 0.84 to 0.62 mL/cmH₂O/kg (p= 0.04) and respiratory resistance (R_{rs}) increased from 19.7 to 26.3 cmH₂O//L/s (p= 0.06) immediately following treatment. There was no significant group change in the eight control subjects. There was no significant difference between the groups with respect to physiotherapy requirements or changes in FEV₁ post-operatively. A moderate to large amount of sputum were cleared during the physiotherapy treatments in six of the eight patients.

Conclusion: The short-term deterioration in respiratory mechanics after physiotherapy under anaesthesia was an unanticipated result. This may be due to any part or combination of the treatment techniques, instillation of saline, airway suction or redistribution of pulmonary secretions. Improved anaesthetic agents and surgical techniques with shorter anaesthetic times may account for the minimal impact on post-operative FEV₁ and physiotherapy requirement. Whilst these treatments may be effective at removing airway secretions, the justification for their continuation needs to be re-evaluated. Further studies are required to examine this phenomenon in greater depth.

Key words: cystic fibrosis, physiotherapy, general anaesthesia, respiratory mechanics

To Cheryl

Whose enthusiasm and fight for life was the greatest inspiration to
all who knew her

University of Cape Town

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*'Yet those who wait for The Lord
Will gain new strength
They will mount up with wings
Like eagles,
They will run and not get tired,
They will walk and not become weary.'*

Isaiah 40:31

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List of abbreviations and definitions

Abbreviation	Definition and units
CO ₂	carbon dioxide
C _{rs}	respiratory compliance, the distensibility of the respiratory system mL/cmH ₂ O or L/kPa (expressed per kg body weight). 1mL/cmH ₂ O = 10.2 mL/kPa
CSP	Chartered society of physiotherapy
CV	coefficient of variation, %, CV = (SD/mean) X 100
ETCO ₂	end tidal CO ₂ , kPa
ETT	endo-tracheal tube
FEF	forced expiratory flow
FEV ₁	forced expiratory volume in one second
FRC	functional residual capacity
FVC	forced vital capacity
GA	general anaesthesia
GOSH	Great Ormond Street Children's Hospital
ICU	Intensive care unit
Kg	kilogram
MBW	multiple breath washout
PEP	positive expiratory pressure
PEEP	positive expiratory end pressure
Physio	physiotherapy
PIP	peak inspiratory pressure, cmH ₂ O, kPa (1cmH ₂ O=0.098 kPa)
R _{rs}	total respiratory resistance, cmH ₂ O/L/s or kPa/L/s (1cmH ₂ O = 0.098kPa/L/s)
SaO ₂	saturation of oxygen in arterial blood, %
SD	standard deviation
Tube leak	tracheal tube leak, %, tracheal tube leak = (V _{TI} -V _{TE})/V _{TI} X 100
TV	tidal volume
V _T	weight corrected tidal volume, mL/kg
V _{TE}	expired tidal volume, mL
Weight	body mass, kg

CHAPTER 1 INTRODUCTION

Cystic fibrosis (CF) is one of the most common life-threatening inherited diseases with an incidence of 1 in 2500 live births (Doull, 2001). Although CF is a multi-system disorder, the main clinical characteristic is chronic lower respiratory tract infection due to excessively viscid mucous resulting in suppurative lung disease.

The prognosis of CF has increased progressively over the past thirty years as a result of a co-ordinated multi-professional approach to care. The greatest benefit is achieved by preventing lung damage with regular physiotherapy and antibiotics, aggressive treatment of any respiratory exacerbations and ensuring adequate nutrition (Dodge et al, 1997). As part of this co-ordinated approach to care, patients with CF will occasionally need to undergo operative procedures under general anaesthesia (GA). The most common elective surgical procedures performed are Nissens Fundoplication, gastrostomy tube insertion or insertion of a permanent subcutaneous vascular access port (Portacath).

GA has historically been associated with a significant morbidity and mortality in CF (4% to 27%) (Salinitre et al, 1964; Doershuck et al, 1972). More recent retrospective studies report a lower mortality incidence of 4.7% (Saltzman et al, 2002) and 0.6% (Weeks and Butland, 1995). The main cause for the morbidity is lung pathology characterised by airway obstruction and atelectasis. Sputum clearance improves ventilation and reduces airway resistance in the short term and in the long term may slow the progression of elastase mediated damage to the airways and mucociliary transport system (Zach, 1991). For this reason, pre- and post-operative care must be directed towards optimal clearance of viscous respiratory secretions. Chest physiotherapy is often performed pre-operatively in these patients following intubation in the anaesthetic room. It is thought that such treatments are an effective method of mobilising peripheral secretions to more proximal secretions. Intubation of the patient enables direct suction access via the endo-tracheal tube (ETT) to clear secretions from the proximal airways. This is considered to be particularly important as patients may be less able to cough and expectorate effectively during the post-operative period treatment due to pain and discomfort. Suction via the ETT also

facilitates collection of sputum for identification of bacterial organisms from patients who are unable to expectorate in order to prescribe the appropriate antibiotic therapy. These treatments may also help to prevent or reduce the anticipated decline in functional residual capacity (FRC) and forced expiratory volume in 1 second (FEV_1) after a general anaesthetic and reduce the physiotherapy requirement in the immediate post-operative period. However, there is no clear understanding of individual circumstances in which these treatments can be effective, the best means of performing them or their effectiveness in treating patients with CF. Few studies have evaluated the immediate and post-operative effects of these physiotherapy treatments. Therefore, the aims of this pilot study were to:

- Evaluate the immediate and post-operative effects of physiotherapy treatments in anaesthetised patients with CF on lung function: Tidal volume (V_T), respiratory resistance (R_{rs}), respiratory compliance (C_{rs}) and peak inspiratory pressure (PIP)
- Evaluate the effects of intra-operative physiotherapy on forced expiratory volume in 1 second (FEV_1)
- Assess the requirement for physiotherapy in the immediate post-operative period, namely four to 24-hour period.

This dissertation is organised within the following chapters; firstly the literature review will examine the evidence related to

- The effects of a GA on respiratory function in patients with CF
- The rationale for physiotherapy in children with CF; in non-intubated and intubated patients
- Individual components of physiotherapy treatments on intubated patients

The second chapter will discuss the study design and methodology and include outcome measures. In the third chapter, results will be tabled and highlighted. The discussion of these results follows in the next chapter correlating the results and the literature review. Finally, the project will be summed up in the conclusion where the future implications of further research in this field and recommendations will be outlined.

CHAPTER 2 LITERATURE REVIEW

2.1 General anaesthesia

The main aims of a general anaesthesia (GA) are reversible loss of awareness and temporary blockade of gross responses to stimulation (Craig, 1981). During anaesthesia skeletal muscular contraction and autonomic responses such as increased heart rate, blood pressure and sweating are inhibited. The three main components of GA are coma, muscular relaxation and analgesia (Forrest et al, 1995). Induction of anaesthesia is the point at which the anaesthetic starts and rapidly progresses to intravenous injection of a short-acting coma-inducing drug such as propofol. Maintenance follows induction with a combination of inhaled anaesthetic (isoflurane, sevoflurane) and intravenous analgesics (morphine, fentanyl) may be given with muscle relaxants (Beasley and Jones, 1985). Inhalation of isoflurane and sevoflurane has been reported to significantly decrease respiratory mechanics of peak inspiratory pressure and respiratory resistance and increase respiratory compliance (Dikmen et al, 2003).

2.2 The effects of general anaesthesia on respiratory function

Many patients undergoing general anaesthesia show changes in lung mechanics, such as decreases in respiratory compliance and FRC, as well as changes in the distribution of ventilation (Eisenkraft, 1990). Anaesthesia can have significant effects on respiratory function; some of which persist into the post-operative period, where in combination with analgesic regimens, they contribute to post-operative abnormalities of respiratory function (Hatch and Fletcher, 1992). The reduction in FRC may be related to diaphragmatic dysfunction thought to be associated with increased abdominal tone and /or a reflex reduction in phrenic nerve activity (Craig, 1981). This reduction in lung volume and encroachment on FRC reduces lung compliance, increases airway resistance and may lead to atelectasis. Dependent lung collapse occurs within fifteen minutes of anaesthetic induction and can last for up to four days post-operatively (Walsh and Young, 1995). Absorption atelectasis may also contribute to the development of post-operative lung collapse. Narcosis reduces the sensitivity of the respiratory centre and decreases the efficiency of carbon dioxide (CO₂) (Joyce and Barker, 1995). A decrease in cardiac output potentially reduces

pulmonary blood flow and alveolar perfusion, thus increasing physiological deadspace. Ventilation/perfusion (V/Q) mismatch is accentuated by the patient being supine on the operating table, respiratory depression and reduced cardiac output (Selsby and Jones, 1993).

The cough reflex is dampened centrally by sedation and opiates and peripherally by any abdominal or thoracic wounds (Brodsky, 1995). The resultant reduction in inspiratory and expiratory volumes makes it more difficult to generate pressure to detach mucus from the airways. Other factors that may increase resistance are reflex bronchoconstriction (for example as a response to intubation) and histamine release by anaesthetic drugs (induction agents, relaxants and opiates) (Hirschman and Bergman, 1990). Inhalation of dry, cold gas bypasses the humidification effect of the upper airways leading to increased mucus viscosity and a high FiO_2 over a period of hours will slow down mucus velocity. Mucociliary clearance ceases altogether after 90 minutes of a GA (Lunn, 1991). These factors may have important implications for patients with CF post-operatively because their clinical susceptibility to increased pulmonary secretions leaves them vulnerable to airway obstruction. This emphasizes the need for intensive airway clearance physiotherapy to aid in the removal of these secretions to prevent pulmonary complications such as lung collapse, increased oxygen requirement and pulmonary exacerbation due to infected bacterial organisms.

2.3 The effects of general anaesthesia on respiratory function in patients with cystic fibrosis

Deterioration in lung function in patients with CF after a general anaesthetic has been well documented with reported decline in functional residual capacity (FRC) and reduced static lung compliance (Price, 1986). Studies published to date have usually been retrospective. Salinitre et al (1964) reviewed 133 anaesthetics in 93 patients over the previous eighteen years. The post-operative mortality was 27% with a high incidence of pulmonary complications (42%). Another study (Doershuck et al, 1972) reviewed 144 anaesthetics over the previous eleven years and noted a post-operative mortality of 4%. Saltzman et al (2002) reported a retrospective review (1970-1994) of 191 operations on 130 with CF. The mortality incidence is reported as 4.7%; nine deaths were from progressive respiratory failure and three from wound infections.

Advances in CF treatment and anaesthesia have substantially decreased the morbidity and mortality in recent years. A recent retrospective study of 165 adults with CF reported 0.6% mortality for surgical procedures despite extremely poor respiratory function (Weeks and Buckland, 1995). A review by Lamberty and Rubin (1985), examined 126 anaesthetics over a three-year period. A retrospective analysis of pulmonary function tests in these patients suggested that anaesthesia had no long-term detrimental effects on the course of pulmonary disease. The authors concluded that, even when multiple procedures are performed, as for instance nasal polypectomy, the effects of the anaesthesia are not harmful. A small prospective controlled study (Richardson et al, 1984) of eleven procedures in six patients with CF having a GA for injection sclerotherapy of varices had shown a significant decline in pulmonary function tests four hours after surgery. The largest falls in pulmonary function were statistically significant in FEV₁ and forced expiratory flow 25-75% (FEF₂₅₋₇₅).

2.4 The rationale for physiotherapy treatments for patients with CF

Physiotherapy remains an integral part of the management of patients with CF. The mainstay of management is bronchial secretion clearance. Airway clearance is commenced at diagnosis, even in infants who are asymptomatic, as there is evidence of pulmonary inflammation and infection before the onset of clinical stigmata (Khan et al, 1995; Armstrong et al, 1995). Postural drainage and percussion is referred to as the traditional method, however, over the years many modalities have been developed to improve patient independence and efficacy of treatment. These include positive expiratory pressure (PEP) mask, Flutter and Cornet (Prasad et al, 2001). These treatments encourage active participation by the patient with intermittent emphasis on huffing, coughing and expectoration. By contrast physiotherapy treatment of intubated patients with CF is similar to treatments performed on ventilated patients in the intensive care unit (ICU). The techniques for intubated patients include: modified postural drainage, saline instillation, manual lung inflation with expiratory chest wall vibrations and suctioning. This treatment technique is occasionally referred to as bronchial lavage in the literature. Bronchial lavage is a widely recognised technique used as a diagnostic tool in the investigation of respiratory disorders and pulmonary infection (Riedler et al, 1995). Physiotherapists may also use bronchial lavage as a non-bronchoscopic technique in which the primary goal may be therapeutic resolution

of atelectasis or retrieval of alveolar fluid for analysis (Dunne et al, 2003). The evidence for these components of physiotherapy will be discussed individually in the next few paragraphs.

2.5 Postural drainage

Postural drainage refers to positioning the patient so that gravity can assist in the removal of secretions from the affected lobe. Some studies have reported that postural drainage in non-ventilated adults added benefit to traditional chest physiotherapy (Sutton et al, 1982; Johnson et al, 1987).

2.6 Manual lung hyperinflation

Manual lung hyperinflation involves disconnection of the patient from the ventilator circuit to provide temporary manual ventilation. In infants a 500ml reservoir bag is used and in older children a 1 litre bag is used which is connected to an oxygen supply. The bag may have a valve or be open-ended so that expulsion of excess pressure is controlled by the operators fingers. Manual hyperinflation involves a slow, deep inspiration by the physiotherapist squeezing the bag, inspiratory pause (when the bag is maintained in its deflated position) and a fast expiration which is achieved by the quick release of the bag. Specific aims of this procedure are to improve tidal volume (TV) and alveolar recruitment by re-inflating areas of atelectasis, thereby improving compliance and ventilation/perfusion matching. Hyperinflation may simulate a cough in self-ventilating patients and thus assist in mucus clearance (Clement and Hubsch, 1968; Bartlett et al, 1973; Stiller et al, 1996). Research examining the efficacy of manual hyperinflation specifically in airway clearance is conflicting or not comparable because of significant differences in technique and methodology (Barker and Eales, 2000). Controversy exists regarding the safety and effectiveness of application of manual lung hyperinflation in intubated patients. Tidal volumes, pressures and FiO₂ are not controlled and there are inherent dangers of barotrauma or hypoxaemia in the absence of additional oxygen (Fox et al, 1978; McKelvie, 1998, Dorges et al, 2000). Whereas some studies suggest the addition of manual hyperinflation in treatment does not offer any advantage (Novak et al, 1987; Eales et al, 1995), others have found manual hyperinflation was associated with an

improvement in respiratory compliance and sputum clearance in mechanically ventilated patients without compromise of cardiovascular stability or gas exchange (Jones et al, 1992; Hodgson et al, 2000).

A manometer should be incorporated into the bagging circuit to monitor the peak inflation pressures. The peak inflation pressures are recommended to be less than 40 cmH₂O in adults (Pearson, 1996) and in paediatrics should not exceed 10cmH₂O above the ventilator pressure (Prasad and Main, 2002) b

2.7 Chest Vibrations

Chest vibrations can be defined as the manual shaking of the chest wall during expiration. Chest vibrations are reported to enhance mucociliary clearance from the central and peripheral airways (Bateman et al, 1981; Ambrosino et al, 1995). During bronchoscopy, vibrations applied to the chest wall have been shown to move secretions into the upper airways (Ciesla, 1996).

2.8 Saline Instillation

Saline instillation (0.9% NaCl) into the tracheal tube of ventilated patients is frequently used to loosen thick, sticky secretions and stimulate a cough in non-paralysed patients (Gibbs et al, 1997). Some studies have shown that saline instillation is well tolerated in infants and may be helpful in removing secretions adherent to the chest wall (Shorten, 1991; Whitnack, 2000), while other studies have reported that it is detrimental in terms of oxygen saturation and may not be clinically effective (Swartz et al, 1996; Schwenker et al, 1998). Although some authors have continued to support the use of saline (Burton and Hodgkin, 1984), this is not based on controlled research studies.

2.9 Physiotherapy treatments during a general anaesthetic of patients with CF

In the literature there are only two studies (Reas and Hackett, 1968; Wordsworth et al, 1996) evaluating the effects of physiotherapy; and one is a randomised clinical study (Wordsworth et al, 1996). Randomised clinical studies are considered the gold standard of research methodology. Reas and Hackett (1968) report the results of 36 tracheal lavage procedures in 25 patients with CF. A long (averaged one hour per treatment session) and vigorous treatment regimen was applied which included instillation of n-acetylcysteine (60-90ml in total), postural drainage, manual hyperinflation and suctioning. Improved forced vital capacity (FVC) and exercise tolerance, resumption of linear weight and height gain were reported to justify the risks of the procedure. Risks included bradycardia (including arrest), hypotension and an associated morbidity with six patients dying seven months after the procedure.

The most recent study reported the findings of a two-year prospective study of 24 children with CF randomised to either receive bronchial lavage (physiotherapy) or not (Wordsworth et al, 1996). Thirteen patients received bronchial lavage and there were eleven controls. The primary outcome measure was the duration of post-operative physiotherapy. A secondary outcome was the frequency of post-operative fever as bronchial lavage has been reported to increase inflammation in the airways. Post-operative physiotherapy requirements in the treated group were smaller than the non-treated group, but did not reach a significant level. Two patients in the bronchial lavage group developed episodes of mild fever but this settled within 24-hours. One patient in the bronchial lavage group developed a pneumomediastinum post-operatively which resolved spontaneously. This was thought to be due to over-vigorous manual lung hyperinflation and not directly due to the bronchial lavage. The impression from the study was that bronchial lavage is not associated with clinical deterioration and is a useful adjunct to the physiotherapy management of patients with CF requiring a GA. This study did not include lung function parameters.

In view of the limited evidence, the current study was considered necessary to identify the acute effects of physiotherapy treatments in the post-operative period on ventilated children with CF. Outcome measures used in previous studies may not be of clinical value to influence current physiotherapy practice e.g. post-operative fever

as used in the study by Wordsworth et al (1996). Outcome measures that may influence physiotherapy practice include maintaining or improving lung function, and the amount (frequency and duration) of physiotherapy sessions required. FEV₁ is a more sensitive measure of lung function compared to FVC as used in the study by Reas and Hackett (1968) and will be discussed in chapter 4 (Outcome measures). There are no recent studies on this topic and with the introduction of new respiratory monitoring devices such as the 'CO₂SMO Plus' it is now possible to obtain direct and non-invasive measurements of lung function in intubated children (see Chapter 4). The following chapter will discuss the study design and methodology for the study.

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CHAPTER 3 STUDY DESIGN AND METHODOLOGY

3.1. Objectives of study

- To evaluate the immediate effects of physiotherapy for anaesthetised children with CF in terms of: weight corrected tidal volume (V_T), respiratory resistance (R_{rs}), respiratory compliance (C_{rs}) and peak inspiratory pressure (PIP). The rationale for selection of these outcome measures will be discussed in Chapter 4.
- To evaluate the effects of intra-operative physiotherapy on spirometric lung function (FEV_1) 24- hours after surgery and at the first clinic visit following surgery
- To evaluate the requirement for chest physiotherapy in the period 4-24 hours immediately following surgery

3.2 Hypotheses

- Physiotherapy leads to an immediate improvement in respiratory function (measured by the 'CO₂SMO Plus') in the anaesthetised child with CF, defined by:
 - An increase in V_T and C_{rs}
 - A decrease in R_{rs} and PIP
- Physiotherapy in anaesthetised children with CF maintains/improves post-operative measurements of FEV_1 at the first clinic following surgery
- Physiotherapy in anaesthetised children with CF improves the patients' post-operative recovery by reducing the need for physiotherapy within 4-24 hour period immediately following surgery

3.3 Study population and inclusion/exclusion criteria

3.3.1 Inclusion Criteria

- Children attending Great Ormond Street Children's Hospital (GOSH) with a diagnosis of CF confirmed by a positive sweat test and genotype
- Who were to undergo elective surgery; which included insertion of a total implantable venous access device (portacath), ear nose and throat (ENT) surgery insertion or change of gastrostomy, Nissens Fundoplication or other abdominal surgery

3.3.2 Exclusion criteria

- Patients undergoing surgery for lobectomy or pneumonectomy
- Tracheal tube leak >20%. Moderate to large tracheal tube leak (>20%) result in reduced tidal volume delivery and gross overestimation of C_{rs} and R_{rs} . Leaks of less than 20% are more likely to ensure consistent ventilation and reliable measurements of C_{rs} and R_{rs} (Main et al, 2001).

3.4 Ethical approval

The project was reviewed and approved by the Institute of Child Health and Great Ormond Street Hospital for Children, NHS Trust Research Ethics Committee.

Written, informed consent was obtained from parents of children with CF who were recruited into the study (Appendix A). Signed assent was obtained from adolescents who were fourteen years and older (Appendix B).

The study was discussed with the surgeon and anaesthetist prior to each patient study.

Written consent for treatment was included on the surgery consent form. Written consent was also obtained from the parent for photographic material to be used for publication and teaching purposes.

3.5 Study design and randomisation

This pilot study was a randomised controlled clinical trial. The decision to undertake a pilot study was influenced by:

- The importance of assessing the feasibility, accuracy and sensitivity of the 'CO₂SMO Plus' (measuring lung function) in the anaesthetic room
- The need to assess the robustness of the trial design
- The limited time and scope of the MSc programme coupled with relatively small number of patient's with CF undergoing elective surgery

Patients were randomised using a minimisation programme to either receive a physiotherapy treatment whilst under anaesthesia (physiotherapy treatment group) or no intervention (control group).

The computer minimisation programme was used with a sample calculation of 15 in each group. The criteria for stratification were: FEV₁, age, sex and classification of surgery.

Minimisation methods allocate patients to treatment group by checking the allocation of similar patients already randomised, and allocating the next treatment group to best balance the treatment groups across all stratification variables (Pocock, 1984).

3.7 Classification of surgical procedures and surgical incision

3.7.1 Permanent subcutaneous vascular access port (portacath)

The portacath is used for intravenous (IV) antibiotic administration in patients with CF. The portacath consists of a small metal chamber with self-sealing silicone diaphragm. Leading from the chamber is a long flexible catheter. At implantation (under GA) the tip of the catheter is positioned in the superior vena cava, cephalic or jugular vein. A subcutaneous pocket is then prepared on the lateral chest wall under the arm (ipsilateral mid-axillary line). The chamber is connected to the catheter which has been routed subcutaneously to the site and sutured in place.

3.7.2 Nissens Fundoplication

Some children with CF experience severe symptoms of gastro-oesophageal reflux that is not controlled by oral medication. In these cases a Nissens Fundoplication under GA is required. The procedure is performed laparoscopically with two pin-point incisions either side of the naval. Via this trans-abdominal approach the fundus of the stomach is mobilised and wrapped around the lower oesophagus

3.7.3 Gastrostomy tube feeding

Long-term supplementary tube feeding may be necessary for some children with CF if there is documented period of inadequate growth (height and weight) secondary to an inability to meet energy requirements. The gastrostomy tube is introduced percutaneously with an endoscope under GA into the stomach (left mid quadrant).

3.7.4 Nasal polypectomy

Nasal polyps occur in about 10% of children with CF (Doull, 2001). Aetiology is uncertain but may be related to infection, allergy, immune factors and abnormal ciliary function. Polyps are usually asymptomatic but can result in chronic nasal obstruction, which increases airway resistance and can lead to snoring. If polyps are unsuccessfully treated with a steroid nasal spray, surgery is considered to remove the polyps.

3.8 Methodology

3.8.1 Pre-surgery:

- FEV₁ data was prospectively collected from two CF clinic visits prior to surgery. This was to assess the individual variability of FEV₁. The two visits ranged from one to two months and three to four months prior to surgery.
- In all cases, patients involved in the study received one to two weeks of intravenous (IV) antibiotics prior to surgery. This was routine management and not administered for the purposes of this study. During this time the researchers was given the opportunity to explain the study to the patient and parent(s). They were also given information sheets and were allowed time (approximately 5 days) to consider whether they would like to participate in the study.
- After admission to the hospital ward, routine spirometry (FEV₁) was performed 24-hours before the surgery.
- The patients were randomised to receive physiotherapy (Appendix C) or no physiotherapy treatment in theatre prior to surgery.

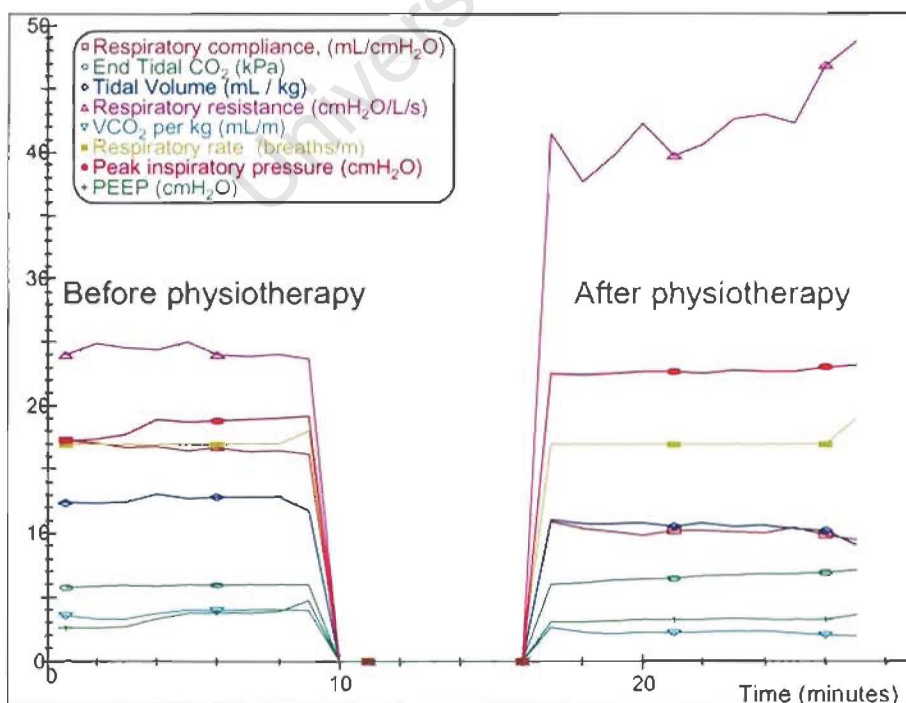
3.8.2 On the day of surgery:

- Many patients did not receive pre-anaesthetic physiotherapy as they were first on the allocated anaesthetic morning time slot and there was not sufficient time to

carry out this treatment. Pre-anaesthetic physiotherapy during the IV admission was not standardised as treatment is individualised to suit the needs of the patient and ensure optimal sputum clearance.

- After induction of anaesthesia, intubation and stabilization of the patient in the anaesthetic room the 'CO₂SMO Plus' was prepared and the flow sensor (Figure 2) was attached between the ETT and the ventilator circuit.
- The 'CO₂SMO Plus' was used to measure lung function parameters for five minutes before and after treatment in the physiotherapy group, and five minutes before and after no intervention in the control group. In a previous study involving a similar population group of intubated pharmacologically paralysed patients, a five minute data collection interval yielded comparable results with data collected over longer periods (up to forty-five minutes) (Main, 2001). It was thus felt that this interval would be sufficient to obtain valuable data while not substantially increasing anaesthetic time.

Figure 1: Example of trend data before and after a Physiotherapy treatment in one individual



- If there was no intervention performed in the control group, then measurements were continuous for ten minutes – dividing into five minutes pre- and five minutes post-control.
- Disconnection and reconnection of the flow sensor from the ventilator circuit were unlikely to cause any change in respiratory function measurements. A previous pilot study on ten patients evaluated the effects of disconnecting and reconnecting the sensor on the continuity of respiratory function parameters (Main PhD, 2001). The author showed that mean changes were negligible and that the 95 % confident intervals of the mean differences were small.
- The anaesthetist was asked to ensure minimal tracheal tube leak by using a cuffed ETT. The anaesthetist was also asked to keep the ventilator settings constant (tidal volume and respiratory rate) before and after the physiotherapy or control interventions, if clinically feasible, to enable accurate comparisons of the respiratory parameters.

3.8.3 Physiotherapy treatment:

- In the physiotherapy group after five minutes of baseline respiratory function measurements, physiotherapy treatment was commenced by one or two senior physiotherapists (including the principal researcher).
- The 'CO₂SMO Plus' was disconnected and treatment commenced with **positioning** the patient in an appropriate modified postural drainage position, either from chest x-ray findings or auscultation findings. Positioning did not use a head-down tip, but positions used included supine, left and right side lying.
- **Saline** (0.9%) of 0.25-0.75ml/kg was instilled into the ETT using a syringe. These volumes are similar to those used during bronchial lavage at this hospital.
- The ventilator circuit tubing was removed and the manual hyperinflation bag was connected to the ETT. **Manual hyperinflation** was then performed by either the anaesthetist or second physiotherapist. Manual hyperinflation involved two to

three tidal volume breaths followed by a large inspiration, a pause at end-inspiration followed by a quick release of the bag during which time expiratory vibrations were applied to the chest wall by the physiotherapist. The therapists hands were placed on the chest wall and, during expiration, a vibratory action in the direction of the normal movement of the ribs was transmitted through the chest using body weight. The vibratory action was a fine movement. This cycle was repeated three to four times or until secretions were loudly audible.

- The **ETT** was suctioned by the physiotherapist after secretions had been mobilised.
- The catheters were graduated suction catheter (Meddis). When suctioning the ETT the external diameter of the catheter did not exceed 50% of the internal diameter of the airway.
- Standardised negative suction pressure of 20kPa (150mmHg) was used for all suction procedures.
- A clean suction procedure commenced by gently introducing the catheter into the ETT without negative suction pressure to 1cm below the tip of the ETT. Suction pressure was applied prior to withdrawal of the catheter using constant negative suction pressure. The catheter was withdrawn without rotation of the catheter around the tracheal wall. Negative suction pressure was applied for less than 10 seconds.
- A new suction catheter was used for each suction procedure.
- The sputum suctioned was graded into white, yellow, light green, dark green, brown and red grades. Agreement was obtained by three physiotherapists on the colour of the secretions obtained.
- The clinical physiotherapist repeated the procedure until no further secretions could be suctioned or breath sounds were clear or had improved on auscultation.

- The physiotherapy treatment was discontinued if any adverse changes in vital signs were noted. All treatment details were carefully recorded (for example, amount of saline instilled or sputum suctioned).

3.8.4 Control group:

- In the control group, no formal protocol was given to the anaesthetist. The anaesthetist was to use his/her clinical judgement as to what, if any airway clearance procedures were deemed appropriate.

3.8.5 Post-surgery:

- The frequency and duration of chest physiotherapy treatments were documented in the 4 to 24-hour period immediately after surgery.
- The patient was assessed during the day by the ward physiotherapist as to the need for physiotherapy during the 4 to 24-hour post-operative period. If the next physiotherapy session were required after 16:30 (end of normal working hours), the ward physiotherapist would request the on-call physiotherapist to assess the patient. Criteria for after-hour assessment included retained secretions which the patient was unable to clear her/himself, reduced levels of oxygen saturation, and a change in oxygen requirement or any change in breath sounds on auscultation. In the evening the registrar doctor of the ward assessed the patient's need for after-hours physiotherapy.
- All physiotherapy interventions were documented in the patients physiotherapy records using the Chartered Society of Physiotherapy (CSP) standards on documentation of notes.
- Routine spirometry (FEV_1) was performed 24-hours after the surgery. The treatment the patient received in theatre was concealed from the respiratory technician performing the spirometry.
- FEV_1 data was collected from the first CF clinic visit post-surgery that ranged from one month to three months.

Figure 2: Anaesthetised patient attached to the 'CO2SMO Plus' and portable computer



3.9 Equipment, Reliability and Validity

3.9.1 'CO₂SMO Plus'

In theatre respiratory function was measured using the 'CO₂SMO Plus', a portable-device capable of non-invasive measurements of respiratory mechanics in ventilated patients. The proximal attachment of the flow sensor between the endotracheal tube and the ventilator circuit avoided potential errors associated with gas compression in the ventilator tubing (Cannon et al, 1999). The 'CO₂SMO Plus' records four variables: pressure, flow, time and carbon dioxide (CO₂) concentration, from which several respiratory parameters were automatically calculated, including V_T , R_{rs} and C_{rs} .

3.9.1.1 Reliability and Validity of the 'CO₂SMO Plus'

Investigations were previously carried out by (Main, 2001; Main et al, 2003) to validate the accuracy, volume recordings and dead space of the device. In vitro evaluation of the 'CO₂SMO Plus' sensors demonstrated < 5 % measurement error for volume integration over a flow range of 0.3-20L/min (neonatal sensor) and < 3 % measurement error over a flow range of 2.5-130L/min (adult sensor). Similarly, calibration checks of the pressure transducers using simultaneous measurement from a Digitron pressure manometer (P200UL, Sifam Instruments Ltd., Devon, UK) revealed measurements were within 3% of applied pressure over a range of 2-70 cm H₂O (0.2-5.9kPa). The least squares algorithms employed by the 'CO₂SMO Plus' to calculate R_{rs} and C_{rs} were checked against linear regression of raw data points and found to be accurate to within 5%. In addition, C_{rs} measurements were checked against known values of C_{rs} on a Manley neonatal lung simulator and measurement errors were found to be < 5% for the full clinical range of respiratory rates and peak inspiratory pressures, irrespective of ventilation modality. The author concluded that the 'CO₂SMO Plus' was an accurate and useful tool for measuring respiratory function in ventilated children. The 'CO₂SMO Plus' has recently been reported to be capable of measuring V_T accurately in ventilated infants and children when compared to the Servo 300 (Castle et al, 2002).

3.9.2 Jaeger Masterscreen

The Jaeger Masterscreen (version 4.3) allowed the measurement of FVC and FEV₁. The system consists of a computer and standard measurement programmes: spirometry, flow volume and an animation programme. The patient was asked to close his/her nose with the nose clip, take the mouthpiece and insert it into his/her mouth with a good seal. He/she was instructed to perform a few tidal volume breaths, then a maximum inspiration followed by a forced maximal expiration. Three recordings were measured and the best value of the three was recorded.

3.9.2.1 Reliability and validity of the Jaeger Masterscreen

Calibration of the Jaeger Masterscreen was performed by the respiratory technician before use on each patient. A calibration pump with a volume of 2 litres was used for the calibration and was attached to the pneumotach. Calibration was carried out under ambient conditions, namely, current temperature, current barometric pressure and current humidity. The piston was pulled back and forth regularly until volume strokes were displayed on the screen. Volume calibration was automatically ended after the set number of strokes had been reached.

CHAPTER 4 OUTCOME MEASURES

The primary outcomes related to this study included

- R_{rs} , C_{rs} , V_T and PIP measured five minutes before and five minutes after physiotherapy or control using the 'CO₂SMO Plus'
- FEV₁ measured 24-hours before after surgery and one to three months after surgery
- The amount (number of physiotherapy sessions and period of time) of physiotherapy required in the 4 to 24-hour period post-surgery

4.1 Respiratory resistance (R_{rs})

Respiratory resistance expressed in cmH₂O/L/s is defined as 'the pressure required to move gas at a flow of 1L/s' (West, 1995). It is defined by the combination of airway resistance and tissue resistance. R_{rs} is a sensitive measurement of respiratory function in ventilated children. Airway resistance is proportional to the fourth power of the radius of the airway, so even small changes in calibre can lead to marked changes in airway resistance, for example secretions. Significant reductions in R_{rs} in paediatric populations after physiotherapy have been documented (Prendiville et al, 1986; Fox et al, 1978). R_{rs} decreases with age as airway calibre increases with growth (Manczur et al, 2000). Airway calibre may, in addition, be influenced by bronchial smooth muscle tone, mucosal oedema, scar tissue, secretions or thickening of the airway wall due to muscle hypertrophy or stenosis, as well as the presence of the tracheal tube (Hatch and Fletcher, 1992). The tracheal tube in paediatric patients is almost the size as the trachea, and therefore contributes a small relatively small proportion of the overall R_{rs} . R_{rs} varies more within and between individuals than does compliance, and these differences may be explained by non-laminar air flow and the length and degree of compression of the tracheal tube or fluctuations in airway smooth muscle tone (Hjalmarson, 1994).

4.2 Respiratory Compliance (C_{rs})

Compliance expressed in mL/cmH₂O is the measure of the distensibility or elasticity of the respiratory system and is dependent upon and defined by the relationship between volume and pressure in the lungs (West, 1995). If the lung easily inflates it is said to be compliant, however, if the lung is stiff or difficult to inflate it is considered to be non-compliant (Widdicombe and Davies, 1991). The compliance of the chest wall decreases after approximately six months of age with the development of muscles, rib ossification and the stiffening of the chest wall (Motoyama and Davis, 1990). Respiratory system compliance depends on numerous factors including delivered expired tidal volume (V_{TE}), FRC, water content of the lung, tissue elasticity, surfactant action, pulmonary blood flow and volume and the visco-elastic properties of the respiratory system (Fletcher, 1991; Hjalmarson, 1994). The separate components of physiotherapy such as manual hyperinflation, saline instillation and expiratory chest wall vibrations may influence C_{rs} . Manual hyperinflation has been shown to improve C_{rs} (Jones et al, 1992) whilst negative suction pressure has been associated with collapse of alveoli and a reduction in C_{rs} (Velasquez and Farhi 1964). Severity of lung disease may also be important in determining the response of C_{rs} to physiotherapy.

4.3 Tidal volume (V_T)

Normal tidal volume during spontaneous breathing is 7ml/kg. During pressure pre-set mechanical ventilation, maldistribution of tidal volume in relation to pulmonary blood flow as well as a tendency to develop atelectasis may result in reduced tidal volume delivery. V_T is adjusted directly in volume-limited mode but in pressure-limited mode is controlled indirectly by adjusting the inflating pressure (PIP minus PEEP). Excess secretions and collapsed alveoli influences V_T by causing a reduction in V_T . A study found an association between improved compliance and recruitment of atelectatic lung, presumed due to an increase in V_T (Macnaughton 1997).

4.4 Peak inspiratory pressure (PIP)

The time-cycled ventilator delivers a pre-defined V_T regardless of the changes in other respiratory parameters. The PIP is then dependent on the patient's dynamic compliance (Kacmarek et al, 1996). Thus in patients receiving this mode of ventilation, clinical changes which result in a decreased C_{rs} or higher airway resistance would be reflected by an increase in measured PIP (Henning, 1999). The ventilator has to deliver higher pressures to achieve the pre-set volume. In this form of ventilation, PIP is a more useful and responsive measure of underlying changes in respiratory function.

4.5 FEV₁

Lung function measurements are performed to describe the condition of the lungs for diagnostic purposes and subsequently to monitor any changes that might have occurred. FEV₁ can be defined as the volume of gas expelled in the first second by a forced exhalation from a full inhalation. FEV₁ is a measure of small airway function that assesses the severity of the disease and whether there has been clinical improvement or deterioration (Dinwiddie, 1997). This is considered the 'gold standard' of lung function measurement in CF. The children perform lung function measurements from the age of five and they are routinely performed at clinic visits by the respiratory technicians.

Normal values are available which take into account the child's gender and height (Polgar and Weng, 1979; Rosenthal, 1993). Abnormal values are defined as those recognised to be outside the normal range of two standard deviations for sex, height and age (Spicer and Kerr, 1966). This usually requires a reduction of approximately 10-15% from the predicted values. FEV₁ > 80% of the predicted mean are considered normal. FEV₁ values of 60-79% is graded as mild, 40-59% as moderate and < 40% as severe pulmonary dysfunction. (American Thoracic Society, 1986).

4.6 Data management

Lung function parameters: V_T , R_{rs} , C_{rs} and PIP were measured continuously and generated data files which were stored on a portable computer.

Data recorded electronically by the 'CO₂SMO Plus' were exported to Microsoft excel software. From the Excel program, data was exported to a statistical software program for analysis (SPSS). Respiratory parameters not calculated by the 'CO₂SMO Plus' e.g. V_T expressed per kg and tracheal tube leak, were calculated from raw data on SPSS. Data collection intervals were identified at five minutes before physiotherapy/control and five minutes after physiotherapy/control. These data were entered on a spreadsheet in SPSS and included details of the treatment received, tracheal tube size and any other relevant data.

4.7 Statistical analysis

Patients with a tracheal tube leak >20% during the data collection interval were excluded from analysis. Patient details were tabled to summarise the data most efficiently. Statistical analysis was performed using SPSS. Volume of sputum suctioned per kg was expressed as a weight corrected value (mL/kg) and a mean value and minimum-maximum range was calculated. The same test was used for the amount of saline used per kg.

The mean values over five minutes of V_T, R_{rs}, C_{rs} and PIP before and after the intervention for each patient was calculated and a paired sample t-test was used to compare values after treatment and differences between groups. The standard deviation and 95% confidence interval were included in the table to reflect individual variation in response to the treatment. When comparing the 'CO₂SMO Plus' respiratory parameters, a group average was calculated from physiotherapy and control groups. Mean group changes after the intervention were also compared using an independent unpaired t-test to look for differences between physiotherapy and control.

Simple scatter graphs (per group) were constructed comparing mean individual patient values for V_T, R_{rs}, C_{rs} and PIP before and after the physiotherapy or control.

FEV₁ data collected was expressed as percentage predicted. Mean FEV₁ group values were calculated and the standard deviation and 95% confidence interval were included in the tables.

CHAPTER 5 RESULTS

Between August 2000 and September 2002, eighteen patients with CF were recruited to the study. The median age of the patients was 12 years 1 month (range: 2 years 3 months to 15 years 2 months). The median body weight range was 41.3kg (range: 14.5 to 61.3 kg).

Data from two patients were excluded from analysis of acute intra-operative respiratory function. One patient from the physiotherapy treatment group was excluded as he had a tracheal tube leak >20% and one patient from the control group required emergency physiotherapy treatment requested by the anaesthetist immediately following intubation which precluded inclusion in the study protocol. One patient was excluded from FEV₁ analysis as he was too young and unable to perform spirometry. Data were thus analysed in a total of 16 patients, 8 in each group.

In the anaesthetic room a time-cycled ventilator was used for all patients, in effect generating volume-controlled ventilation. Since no changes in ventilation setting were made in the periods before, during and after treatment, no substantial changes in V_T were anticipated. Changes in PIP were expected to reflect underlying changes in R_{rs} or C_{rs} in response to the intervention. All patients were sedated and paralysed hence changes in R_{rs} and C_{rs} would not have been influenced by changes in spontaneous breathing patterns but were likely to be related to the treatment or control.

The details of the patients are listed in Table 1 below.

Table 1 Patient details

	Physiotherapy	Control
TOTAL	9	9
Sex: Male	3	5
Female	5	5
Age: 0-5 years	1	0
6-10 years	3	2
11-16 years	5	7
Procedure:		
Portacath	7	6
Nissens/Gastrostomy	0	2
Polypectomy	1	1
Ophthalmology	1	0
Disease severity:		
FEV ₁ 80-100%	2	0
FEV ₁ 50-79%	6	5
FEV ₁ <49%	0	4
Too young	1	0

5.1 Patients excluded

One patient in the physiotherapy group who did not appear, on initial assessment, to have a tracheal tube leak subsequently developed a substantial leak after treatment and had to be excluded from data analysis. In the control group, one patient immediately following intubation, showed evidence of copious secretions in the oropharynx. On auscultation there were marked decreased breath sounds of the left lung and the anaesthetist, who suspected a total or partial collapse of the lung, requested that physiotherapy be initiated immediately to clear the secretions and re-inflate the lung. In view of this the normal study protocol had to be abandoned and no measurements of respiratory function were made. Copious secretions were yielded during this treatment and treatment was terminated when the breath sounds were equal in both lungs.

5.2 Physiotherapy Group

Data were analysed from eight patients. The mean duration of physiotherapy treatment was 11.4 minutes (range 10 –15 minutes). The mean amount of saline instilled was 0.5ml/kg (range 0.25-0.64ml/kg). The mean amount of sputum suctioned was 0.15ml/kg (range 0.07-0.27ml/kg). The mean number of suction catheters used per treatment was 5 (range 3-7). The sputum of two patients was graded as 'light green' colour and that of six patients was graded as 'dark green'. During intra-operative physiotherapy a negative suction pressure of 20kPa (150mmHg) was used. This pressure was controlled throughout the study.

5.3 Control Group

Data were analysed from eight patients in the control group. Saline instillation, manual hyperinflation and suction were not performed. There was no disconnection from the ventilator and 'CO₂SMO Plus' measurements were performed continuously for 10 minutes.

Table 2 Demographic comparison between Physiotherapy and Control groups

	Physiotherapy	Control
Age (years)	12.3 (3-15)	12 (6-15)
Sex: M/F	3:5	4:4
Weight (kg)	44.6 (14.5-61)	43.1 (18-61.3)
Length of surgery (minutes)	59 (40-90)	63 (20-160)
Length of anaesthesia (minutes)	100 (70-130)	85 (45-200)

From Table 2, it can be seen that the mean age was similar in both groups, as was the ratio of males to females. The mean duration of surgery was similar in both groups. However, the mean length of time of the anaesthesia was greater in the physiotherapy group. This can probably be explained by the additional duration of the physiotherapy treatments.

5.4 'CO₂SMO Plus' measurement results

Changes in respiratory function parameters with respect to V_T , R_{rs} , C_{rs} and PIP after physiotherapy are summarised in Table 3. The control group results are summarised in Table 4. There were no significant group changes in V_T following treatment in the physiotherapy group (Table 3, Figure 2) or the control group (Table 4, Figure 2). This was anticipated since all patients were effectively managed on volume controlled ventilation.

Table 3 'CO₂SMO Plus' Physiotherapy group measurements

Parameter	Before physio (B)	After physio (A)	95% CI (A – B)	P value
V_T (mL/kg)	10.5 (2.9)	9.6 (2.1)	-2.6 to 0.87	0.28
R_{rs} (cmH ₂ O/L/sec)	19.7 (7.8)	26.3 (10.8)	-0.42 to 13.5	0.06
C_{rs} (mL/cmH ₂ O/kg)	0.8 (0.3)	0.6 (0.1)	-0.33 to -0.01	0.04
PIP (cmH ₂ O)	21.9 (3.4)	25.4 (3.9)	-0.3 to 6.6	0.04

In Table 3, V_T decreased slightly but this was not significant. There was a tendency for R_{rs} to increase following physiotherapy that approached significance ($p=0.06$). C_{rs} decreased following treatment reaching statistical significance $p=0.04$. In keeping with a reduction in C_{rs} , group value measurements for PIP increased following treatment with $p=0.04$.

Table 4 'CO₂SMO Plus' Control group measurements

Parameter	Before control (B)	After control (A)	95% CI (A – B)	P value
V_T (mL/kg)	8.4 (2.0)	8.6 (1.9)	-0.41 to 0.92	0.39
R_{rs} (cmH ₂ O/L/sec)	20.9 (6.9)	21.0 (5.1)	-2.1 to 2.1	0.98
C_{rs} (mL/cmH ₂ O/kg)	0.7 (0.1)	0.7 (0.1)	-0.3 to 0.3	0.8
PIP (cmH ₂ O)	21.1 (6.4)	21.8 (6.5)	-0.08 to 0.5	0.07

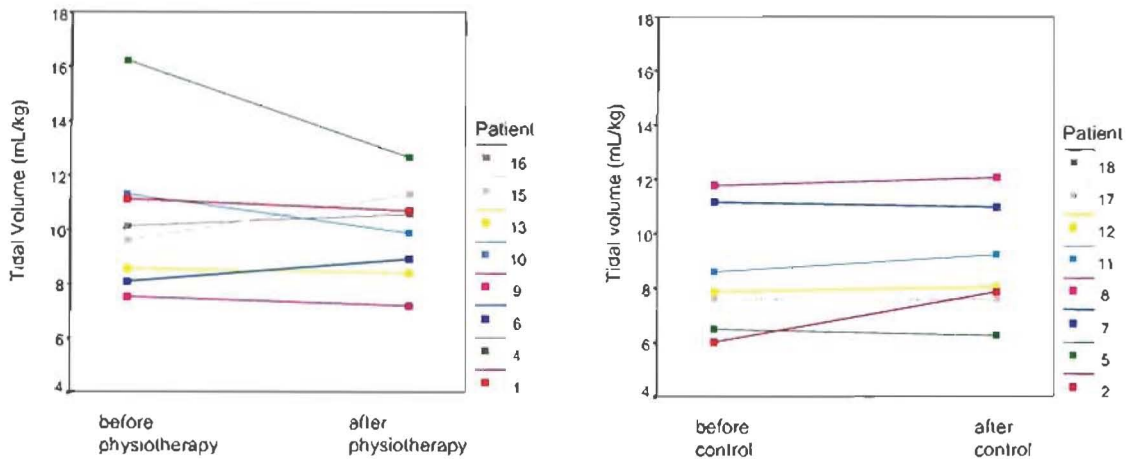
A lower baseline value of V_T can be seen in the control group (Table 4) compared to the physiotherapy group (Table 3). In Tables 3 and 4, physiotherapy and control groups have similar baseline values of R_{rs} , C_{rs} and PIP. The parameters of R_{rs} , C_{rs} and V_T remained relatively stable during the monitoring of the control group. This was in keeping with no intervention as one would not expect any changes in respiratory function. PIP tended to increase slightly which neared significance ($p=0.07$). No changes were made to the ventilator settings during this monitoring period. The observed increase in PIP may be explained by some distal secretions that had shifted during the intubation process and effect of the anaesthetic gas.

Table 5 Comparing mean change post-physiotherapy and control (paired data)

	Number	Mean Change post physio	Mean change post control	95% CI	P value
V_T	16	-0.98 (1.96)	0.23 (0.81)	0.48 to -2.90	0.14
R_{rs}	16	6.53 (8.31)	-0.06 (2.48)	13.6 to -0.44	0.06
C_{rs}	16	-0.14 (0.22)	0.02 (0.03)	0.03 to -0.35	0.08
PIP	16	3.49 (3.78)	0.70 (0.96)	5.97 to -0.40	0.08

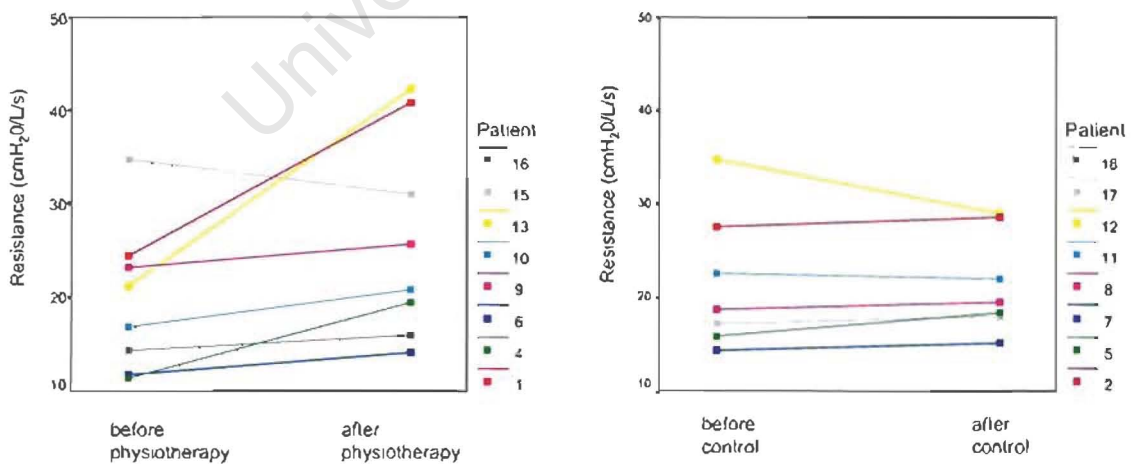
The effects of physiotherapy and control appear to differ in some respects (Table 5). There was no difference in V_T between the physiotherapy and control group mean changes. There was a tendency for C_{rs} and PIP to near significance ($p=0.08$) when comparing the group mean changes. This correlates to the physiotherapy group (Table 3) where C_{rs} and PIP were statistically different ($p=0.04$) following the intervention compared to the control group (Table 4) where the parameters remained relatively stable. R_{rs} approached significance ($p=0.06$) when comparing group mean changes.

Figure 3: Individual changes in tidal volume following Physiotherapy and Control



When individual changes in the physiotherapy and control group are examined (Figure 3) it can be seen that V_T in Patient 4, was reduced by 56% and in Patient 10 by 20% following physiotherapy treatment. Patient 4 had a high baseline value for V_T compared to the other patients.

Figure 4: Individual changes in respiratory resistance following Physiotherapy and Control



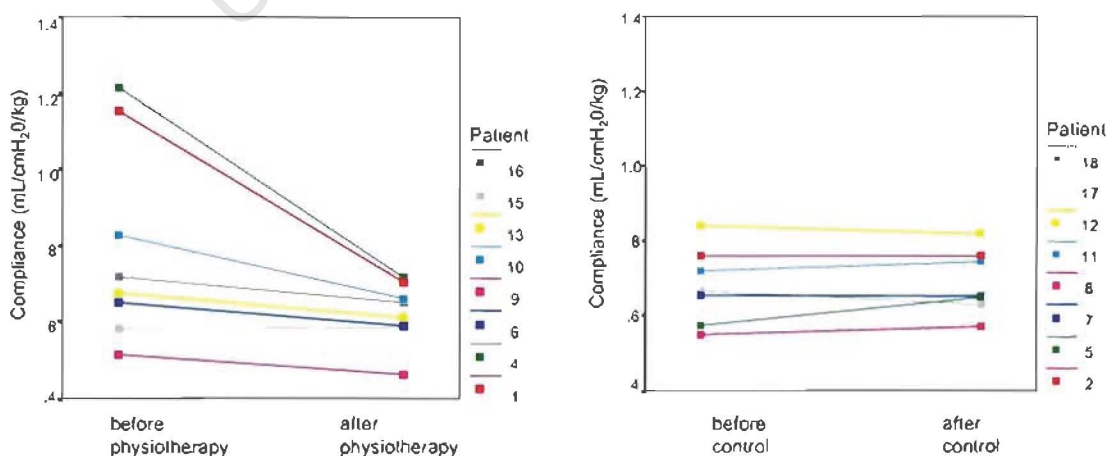
In Figure 4 it can be seen that R_{rs} increased significantly in Patients 1 by 71 %, Patient 4 by 80 % and Patient 13 by 100 % after the physiotherapy treatment. These were accompanied by a significant reduction in C_{rs} in Patients 1 and 4. A small amount of

sputum was obtained from suction of these patients. In the control group there were no significant changes in individual patient measurements.

Patient 1 was 2 years and 3 months at the time of the study. He has had regular IV antibiotics every three months because of the severity of his lung disease. His chest x-ray score is 22, indicating advanced pulmonary disease according to the Crispin Norman classification (The normal range value for this score is 0-5). He does not expectorate and sputum obtained from suction in theatre grew a pathogen (*Pseudomonas aeruginosa*) that he had not grown in the previous year cough swabs. This is a chronic pathogen that is common in patients with CF and long-term eradication is difficult.

Patient 4 was admitted for minor ENT surgery, he had a $FEV_1 > 80\%$ and his chest x-ray score was 5. He has mild respiratory disease and does not expectorate with cough swabs growing no sputum pathogens. A small amount of green sputum was obtained from suction and grew *Pseudomonas aeruginosa* which necessitated a change of antibiotic management for this patient. The marked deterioration in response to physiotherapy demonstrated by a reduction in V_T , increased R_{TS} and decreased C_{TS} is difficult to explain.

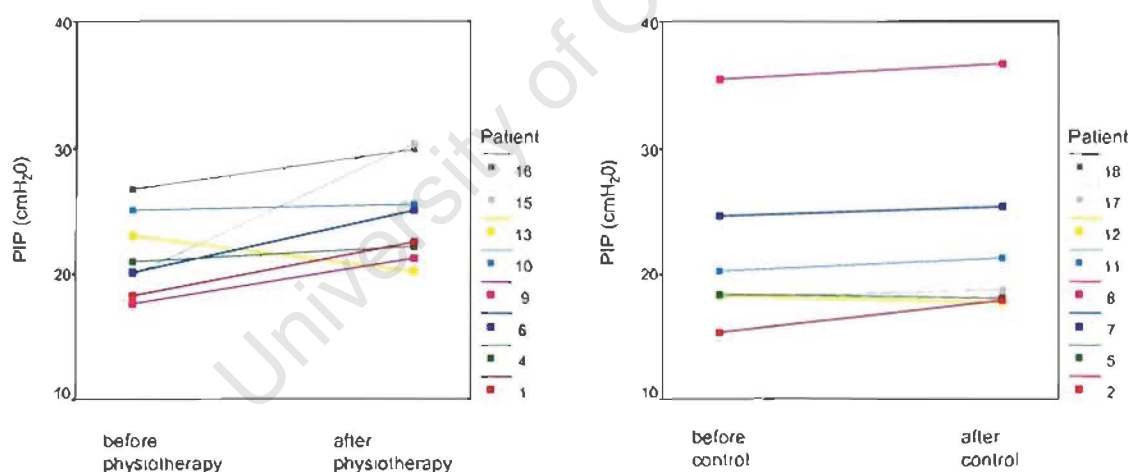
Figure 5: Individual changes in respiratory compliance following Physiotherapy and Control



In Figure 5 it can be seen that C_{rs} was reduced in most patients following physiotherapy. By contrast, C_{rs} measurements remained fairly constant in the control group.

In Patient 1, C_{rs} decreased by 64% and in Patient 4 by 69% following physiotherapy. From Figure 3, these reductions in C_{rs} were accompanied by significant increases in R_{rs} . Both these patients had higher baseline values than the patients in both groups. Patient 1 was too young to perform FEV_1 during this study. His post-operative course was uneventful and he did not require supplemental oxygen following surgery. FEV_1 measurements for Patient 4 following surgery were above 80% within normal predictive values.

Figure 6: Individual changes in peak inspiratory pressure following Physiotherapy and Control



There was a tendency for PIP to increase in Patient 1 by 23%, Patient 6 by 50% and Patient 15 by 12% in the physiotherapy group. This is consistent with the significant decrease in C_{rs} in Patient 1 seen in Figure 5 and increase in R_{rs} in Figure 4. In the control group, Patient 8 had a higher starting value of PIP and V_T from Figure 3

compared to patients in both groups. These values remained constant during the ten minutes of monitoring.

Although PIP increased substantially in Patient 6, from Figure 5 it can be seen that C_{rs} decreased slightly. A large amount of tenacious secretions were cleared during treatment. The anaesthetist remarked that following physiotherapy, manual hyperinflation was easier to perform on the patient implying an improvement in C_{rs} .

5.5 Mean FEV₁

In the physiotherapy group, Patient 1 was too young to perform spirometry. However FEV₁ data from Patient 3 was included (this patient was excluded from 'CO₂SMO Plus' measurements as she had a tracheal tube leak > 20%). FEV₁ measurements in this patient were obviously not affected by tracheal tube leak.

Table 6 Variability of FEV₁

	1-2 months pre-surgery	2-4 months pre-surgery	95% CI	P value
Physio FEV₁ (n= 8)	61.5 (18.8)	66.7 (15.2)	-8.5 to 19.0	0.4
Control FEV₁ (n=8)	55.4 (22.5)	54.0 (15.5)	-14.6 to 11.9	0.81

In Table 6 the mean FEV₁ values were taken from clinic visits prior to surgery. The mean values of the physiotherapy and control groups were compared to assess the variability of FEV₁. The control group had a lower baseline FEV₁ value than the physiotherapy group. There were no significant changes in FEV₁ during clinical visits prior to surgery. Changes in mean FEV₁ in the control group were negligible, whereas mean FEV₁ in the physiotherapy group was slightly different.

Table 7 mean FEV₁ 24-hours pre and 24-hours post-surgery

	24-hours pre-surgery	24-hours post-surgery	95% CI	P value
Physio FEV₁ (n=8)	69.0 (9.5)	63.3 (15.6)	-13.4 to 1.9	0.12
Control FEV₁ (n=8)	60.3 (15.7)	51.8 (12.1)	-17.1 to 8.5	0.07

FEV₁ was recorded 24-hours pre-surgery and then in the 24-hour period following surgery (Table 7). There was an increase in FEV₁ 24-hours pre-surgery compared to 1-2 months pre-surgery (Table 6). This could probably be explained by routine practice of intravenous antibiotics pre-surgery for all patients with CF. Mean FEV₁ values were reduced in both physiotherapy and control groups with the 24-hour period after surgery. This was not significant in the physiotherapy group, but approached significance in the control group (p=0.07). Confidence intervals suggest that these values may have reached significance with a larger study population. Seven out of sixteen patients showed a reduction in FEV₁ of more than 10%. Four of these seven patients were from the physiotherapy group. Respiratory technicians reported that during the 24-hour post-surgery measurement the majority of children were unable to perform optimal spirometry as they complained of pain from the incision site.

Table 8 Mean FEV₁ at the first clinic visit after surgery

	24 hours pre-surgery	1st visit post-surgery	95% CI	P value
Physio FEV₁ (n=8)	69.0 (9.5)	58.9 (21.5)	-26.0 to 5.8	0.18
Control FEV₁ (n=8)	60.2 (15.7)	56.1 (23.1)	-17.7 to 9.5	0.50

In Table 8 the first clinic visit after the surgery ranged from a four to six week period. The mean values of FEV₁ are lower at the first clinic visit post-surgery compared to pre-surgery recordings, however, no statistical significance was reached in either group. At the first clinic visit post-surgery (four to six weeks following admission),

four out of eight patients (50%) in both physiotherapy and control groups showed a reduction in FEV₁ of more than 10%. One patient in each group showed an improvement in FEV₁ of more than 10%. FEV₁ group data at visit 1 post-surgery approached pre-surgery values and differences were not significant. FEV₁ values recorded at the first visit post-surgery was almost identical to the 1-2 months pre-surgery (Table 6) in both groups. This indicated that the effects of pre-surgery intravenous antibiotics and the surgery were now negligible.

5.6 Physiotherapy requirements in the immediate 4-24 hour post-operative period

Two patients required on call/night time physiotherapy treatments within 4 to 6-hours after the surgery – one in each group. Within the 24-hour period both physiotherapy and control groups received an equal amount of physiotherapy treatments by a senior physiotherapist. The physiotherapy treatments consisted of two to three sessions within the 24-hour period. Nine of the sixteen patients (five in the physiotherapy group and four in the control group) were discharged to their local hospital 12 to 24-hours after the surgery.

CHAPTER 6 DISCUSSION

The hypotheses proposed at the commencement of this study were that:

- Physiotherapy would improve lung function immediately following treatment, reflected by an increase in V_T and C_{rs} and a reduction in R_{rs}
- Physiotherapy would maintain or improve lung function (FEV_1) in the long-term measured at the first clinic visit post-surgery
- Physiotherapy would improve the post-operative recovery in patients with CF undergoing an elective surgical procedure by reducing the requirement for chest physiotherapy in the immediate 4-24 hour period after the surgery

The results of the study showed that in the physiotherapy group C_{rs} was reduced and R_{rs} was increased immediately following treatment. FEV_1 recorded at the first clinic post-surgery was not significantly reduced compared to FEV_1 24-hours pre-surgery. There was no difference between the physiotherapy and control groups in terms of physiotherapy requirements in the immediate post-operative period.

The acute, but short-term deterioration in respiratory mechanics observed immediately after physiotherapy under anaesthesia was an unanticipated result. Even though this deterioration in respiratory function was short-term, it raises the need to re-evaluate the justification for such treatment. It is difficult to determine which individual aspects of treatment or combination of factors may have contributed to the deterioration. The deterioration in respiratory mechanics immediately following physiotherapy was not reflected by undue reduction in FEV_1 shortly after surgery. More over, physiotherapy cleared a moderate to large amount of sputum during most of these intra-operative treatments. Removal of sputum decreases the risk of airway obstruction and treatments may help to mobilise peripheral secretions, facilitating ease of expectoration post-operatively. Sputum clearance also reduces the ideal pulmonary medium for bacterial culture and a sputum specimen obtained from suction can identify pathogens upon which antibiotic therapy can be administered. While these arguments may support the continuation of these treatments, the control group demonstrated no obvious decline in respiratory function despite lower baseline FEV_1 . Unfortunately, randomisation produced a small bias, reflected by a lower FEV_1 in the control group. Advanced severity of disease is more likely to be associated both

with increased secretions and delayed recovery post-surgery. It would be useful in future studies to evaluate the effects of physiotherapy under anaesthesia in this patient group. The results of this study may influence future physiotherapy policy direction on whether or not these treatments should be routine clinical practice. A balance between the study results and clinical implications for individual patients needs to be addressed. Routine clinical practice whereby all patients with CF undergoing elective surgical procedures receive physiotherapy under GA may change following the results of this study. The management of patients with CF should also be individualised so as to ensure optimal therapeutic intervention.

The theoretical and clinical implications of these results will be further discussed in this chapter. In addition, the limitations of the study design will be discussed. Finally, the future implications of further research in this field and the application of evidence-based medicine for these treatments will be explored.

6.1 Short-term 'CO₂SMO Plus' effects of physiotherapy

6.1.1 Tidal volume (V_T)

All patients were sedated and paralysed which therefore eliminated spontaneous breathing and ensured no altered respiratory rate which could have affected the parameters of V_T and PIP. Respiratory rate did not vary as a result of physiotherapy treatment and was not influenced by the volume-controlled mode of ventilation.

6.1.2 Resistance (R_{rs})

Airway calibre is influenced amongst other factors, by bronchial smooth muscle tone and the presence of secretions (Hatch and Fletcher, 1992). Following the removal of these secretions, the R_{rs} should decrease. The anticipated reduction in R_{rs} in the physiotherapy group following removal of secretions did not occur. The increase in R_{rs} may be explained by the physiotherapy treatment, involving saline instillation, positioning and manual hyperinflation causing redistribution of secretions resulting in alteration of air trapping or bronchospasm in those with hyper-reactive airways. In the

physiotherapy group there were a greater number of disconnections from the ventilator for the suctioning procedure to remove secretions. The frequent disconnections may have contributed to the increase in R_{rs} . This is in contrast to the control group where there was no intervention and R_{rs} remained constant. Some clinicians claim that the instillation of room temperature saline into the ETT may cause some bronchospasm and thus increase the R_{rs} . Their solution is that warmed saline or administration of IV bronchodilator will reduce the effect of bronchospasm. There is no current evidence in the literature to support the instillation of warmed saline.

6.1.3 Compliance (C_{rs}) and peak inspiratory pressure (PIP)

C_{rs} is the measure of the distensibility or elasticity of the respiratory system and is the ratio of change in volume to change in pressure over the respiratory cycle (Widdicombe and Davis, 1991). Thus, a reduction in V_T would be associated with a reduction in C_{rs} as long as ventilator pressures remained the same. Conversely, if ventilator volumes were constant (as would be expected in this population ventilated on volume controlled mode) changes in C_{rs} would be accompanied by changes in PIP. In this study, C_{rs} decreased in the physiotherapy group statistically significantly ($p=0.04$). This may have been due to vigorous movement of expiratory chest wall vibrations or vigorous manual hyperinflation. Manual hyperinflation technique varies amongst clinicians and in this study was performed on four occasions by the anaesthetists. Some studies have reported an improvement in C_{rs} after physiotherapy (Winning et al 1975, Mackenzie et al, 1980), however no change or deterioration has been shown in other studies (Eales et al, 1995). Negative suction pressure has been associated with collapse of alveoli and reduction in C_{rs} (Velasquez and Farhi 1964) and this could explain why there was no change in C_{rs} with the control group where no intervention was performed. Also, in the physiotherapy group, in keeping with the decrease of C_{rs} the PIP increased. This was an exaggerated response in two patients. Patients 1 and 4 where C_{rs} reduced following physiotherapy and PIP increased to counteract the effect of this reduction to maintain adequate ventilation. Physiotherapy and control group mean changes following the intervention approached significance in these respiratory function parameters. This indicates that there is a difference in the procedures performed and the subsequent outcome. There was no intervention

performed in the control group and the respiratory parameters remained relatively stable. In contrast, in the physiotherapy treatment group where treatment consisted of saline instillation, manual hyperinflation with expiratory chest wall vibrations and suction, the respiratory mechanics increased in PIP and R_{rs} and decreased in C_{rs} following the treatment

6.2 FEV₁

Allocation concealment of study groups from lung function technicians who measured spirometry measurements worked well and added to the integrity of the study in removing potential.

FEV₁ group data compared from clinic visits prior to surgery were relatively even. In one individual, however, FEV₁ changed from 61% to 85% at clinic visits pre-surgery. FEV₁ is dependent to some extent on patient effort in blowing, how they are feeling at the time of lung function and the motivation given by the respiratory technician in encouraging the patient. FEV₁ recorded 24 hours prior to surgery was increased in both groups compared to pre-surgery clinic visits. This can probably be explained by the two weeks of IV antibiotics they received prior to the operation.

There was a reduction in both groups of FEV₁ in the 24-hour period after the surgery. This was not significant in the physiotherapy group but approached significance in the Control group. However, seven out of sixteen patients (44 %) showed a reduction in FEV₁ of more than 10%. This is within the range of abnormal values as defined by Spicer and Kerr (1966). In these patients, several factors may have contributed to this reduction, including, the effects of general anaesthesia (Price, 1986; Richardson et al, 1984) and pain or discomfort from the surgery. The validity of measuring FEV₁ 24-hours post-operatively may not helpful in evaluating the effect of the intervention on lung function. The subjective view of patients suggested that post-operative pain limited the optimal performance of FEV₁. Annual FEV₁ changes in patients with CF is variable. The mean (+/- standard deviation) annual change of FEV₁ is reported as 2.2 +/- 6.2 to -2.2 +/- 3.6% (Merkus et al, 2002). Thus the individual changes in the immediate post-operative period represented a large difference relative to these annual figures.

For any long-term data, it would be useful to record the FEV₁ from clinic visits up to a year post-operatively to evaluate the effects of the GA and physiotherapy intervention. However, with any long-term study one needs to consider other variables which may alter the FEV₁. Lung function may improve following commencement of nebulised antibiotics, inhaled steroids or the introduction of regular three monthly IV treatments in hospital. Deterioration in lung function may also occur with repeated pulmonary exacerbations accompanied by weight loss.

6.3 An individual case

A dramatic reduction in C_{rs} and increase in PIP was observed in Patient 4 (Physiotherapy group). The spirometric FEV₁ value for this Patient is >80% and it was thus surprising that physiotherapy had such a significant influence on the acute lung function parameters. It may have been due to acute bronchospasm following saline instillation or in response to physiotherapy techniques such as manual hyperinflation and chest wall vibrations. At the first clinic visit post-surgery, his FEV₁ was the same as his pre-surgery value. The acute effects of response to treatment did not persist to the longer-term as evident by the return to baseline FEV₁. Further investigation is required to investigate factors that influence individual responses to these therapies.

6.4 Insights gained from excluded patients

In the control group, one patient had to be excluded from the protocol because of an urgent need for immediate airway clearance intervention. Although these events are relatively rare, they do occur from time to time. The importance of physiotherapy in the presence of copious secretions and total or partial alveolar collapse is evident (Stiller et al, 1996). The anaesthetist recognised the importance of the physiotherapy intervention and allowed the physiotherapist as much additional time as was needed for the patient to be stabilised prior to the impending surgery. Occasionally the physiotherapist has been called by the anaesthetist to treat a patient in theatre or the anaesthetic room if aspiration was suspected. The aim of physiotherapy treatment was to clear secretions aiding in a successful extubation and improving the post-operative care.

Conversely the other patient was excluded because of a dramatic increase in tracheal leak post-physiotherapy treatment. Sometimes an increase in leak can be attributed to a substantial fall in C_{rs} or an increase in R_{rs} . If this had occurred as a result of treatment, this suggests those individual responses to and the need for physiotherapy is extremely variable. There is a need to assess improved ways of patient selection that would benefit from these treatments.

6.5 Evaluation of methods and equipment

6.5.1 Patient enrolment

Eighteen patients in a twenty-six month period were recruited to the study. Recruitment of the patients was uncomplicated and all were willing to participate in the research project. All patients received intravenous antibiotics for ten to fourteen days prior to surgery which gave the researchers enough time to recruit patients to the study and co-ordinate anaesthetic time with the anaesthetists and surgeons.

6.5.2 Randomisation

The randomised controlled trial worked very well in this setting using the computer minimisation programme. Demographic data of the patients indicated that they were evenly matched for age, sex and classification of surgery. However, there were four patients in the control group with a $FEV_1 < 49\%$, compared to the physiotherapy group in which there were no patients with a $FEV_1 < 49\%$. Two patients in the physiotherapy group had a $FEV_1 > 80\%$ and there were none in the control group. This implied that the control group had in general more severe disease and this was demonstrated by differences in baseline values of FEV_1 . FEV_1 was lower in the control group compared to the physiotherapy group at visits pre-surgery (Table 5) and 24-hours pre-surgery (Table 6). A limitation of this study was that all patients in the physiotherapy group had mild to moderate lung severity and physiotherapy intervention was not assessed in the severe lung disease group.

6.5.3 'CO₂SMO Plus'

No difficulties or problems were experienced with the 'CO₂SMO Plus' and it was found to be straightforward, reliable and safe to use in the anaesthetic room.

In the physiotherapy group, one patient was excluded from analysis of V_T , R_{rs} , C_{rs} and PIP data due to tracheal tube leak >20% (Main et al, 2001). In all cases a cuffed ETT was used and the anaesthetist was asked to maintain as small a leak as possible. This leak was not evident during baseline measurements using the 'CO₂SMO Plus' monitor but developed following treatment and was discovered during analysis. Data were excluded from analysis since the leak would have invalidated measurements of V_T , R_{rs} and C_{rs} . One of the limitations of using the 'CO₂SMO Plus' monitor was that the ETT leak was not evident on the lap-top monitor and only revealed during subsequent analysis. If the leak was seen during monitoring then the anaesthetist would have been asked to help reduce the leak by changing position of the patients head or slight manoeuvring of the ETT. ETT leak in this patient did not effect the ventilator requirements which remained constant even though the leak was >20%.

6.6 Physiotherapy treatment/Control in the anaesthetic room

Where possible, two physiotherapists were required for the physiotherapy treatment in the anaesthetic room and the same physiotherapist may have treated the patient on the ward too. The physiotherapist who treated the patient after the surgery was sometimes the same person who treated the patient in theatre. This may have biased the physiotherapist in decisions on physiotherapy requirements on the ward post-surgery. However, there was pressure to ensure that the anaesthetic time slots were adhered to so that the surgery of other patients on the theatre list did not have to be cancelled. Staffing levels did not always permit excess physiotherapists from whom treatment allocation was concealed. However, only one patient in each group required after-hours physiotherapy which was unlikely to have influenced treatment given or decisions made.

The duration of the physiotherapy treatment and the technique used differed from the Reas and Hackett (1968) study. Physiotherapy in their study lasted approximately one hour whereas the duration in this study was 11.4 minutes (range 10 –15 minutes).

Reas and Hackett used 60-90 ml (per patient) N-acetylcysteine whereas 0.9% NaCl (range 0.25-0.64ml/kg) was used in this study. N-acetylcysteine is an extremely reactive mucolytic and the side effects include coughing, mucosal irritation and bronchial hyper-reactivity (Nagy, 1984; Kupczy and Kuna, 2002). The longer duration of physiotherapy and use of N-acetylcysteine by Reas and Hackett may have accounted for the acute risks of bradycardia and hypotension and associated morbidity with six patients dying seven months after the procedure.

The anaesthetists were not given a specific protocol of what to do with the patient if they were randomised to the control group. One of the senior anaesthetists anecdotally reported that they did regularly perform manual lung hyperinflation and suction on the CF patients. Of the eight patients in the control group, no such intervention was performed on any patients. The above-mentioned anaesthetist was not involved in any of the study patients. The anaesthetists were questioned as to why no treatment was performed and they reported that the patient was stable and there were no indications for treatment.

6.7 Sputum yield

One of the main aims of physiotherapy in patients with CF is to assist with mucus clearance. Mucus in these patients is often tenacious and with the added effects of a general anaesthesia, this would increase the difficulty in clearing secretions from patients who produce large amounts of sputum post-operatively. In the physiotherapy group a moderate to large amount of sputum from six of eight patients was cleared from the lungs during suction. This is particularly important in patients who are unable to expectorate but have a productive cough. A sputum specimen obtained from suction can be helpful in identifying sputum pathogens upon which antibiotic management can be directed. A sputum pathogen was isolated on microscopy culture in one patient that actioned long-term nebulised antibiotic cover. Previous cough swabs in this patient over the past few years failed to grow any organisms. Sputum has always been a controversial outcome measure in physiotherapy because of wide inter- and intra-subject variability. However, in evaluating an individual's response to a specific treatment, it remains, for the clinician an accessible indicator of treatment success, especially in a disease characterised by copious sputum production.

6.8 Was there an increased need for physiotherapy within 24-hour period immediately following surgery?

There was no increased need for physiotherapy within the 24-hour period following surgery. Patients in both physiotherapy and control groups received the same number of physiotherapy treatments. The findings of this study differ from the results of Wordsworth et al (1996) who reported on 13 patients receiving bronchial lavage and 11 controls. They reported that post-operative physiotherapy requirements were smaller in the treated group compared to the non-treated group. This difference may be due to the use of newer surgical techniques such as laparoscopic surgery (Powers et al, 2003), image-guided surgery techniques and improved anaesthetic agents which lead to a shorter anaesthetic. Even though the physiotherapy group had a longer period under anaesthesia compared to the control group, this did not influence physiotherapy requirements post-surgery.

Patient's received the care they would normally receive on the ward. This consisted of regular observations by the nursing staff (see Appendix C), IV antibiotics, analgesia and physiotherapy sessions post-nebulised bronchodilators and mucolytics. The patients were treated first thing in the morning, at midday and then in the afternoon – as standard care practice.

6.9 Limitations of the study

The number of patients undergoing elective surgery varies from year to year and this may have led to a smaller number of patients recruited to the study. The relatively small number of patients lead to variation of baseline values of FEV₁ and "CO₂SMO parameters. More patient numbers would ensure more even distribution of data.

The principal researcher was the lead physiotherapist and sometimes the only physiotherapist performing the physiotherapy treatments. During clinical hours, it was not always possible for other experienced physiotherapists to assist or perform the treatment. The results may not therefore be a fair cross-sectional representation of physiotherapy treatments in general.

Although lung function spirometry is an objective measure of clinical outcome, children with CF do not always perform these tests to their best ability. FEV₁ may therefore not be the most sensitive outcome measurement as variability occurs daily and weekly in patients with CF (Cooper et al, 1990). This may be due to sputum retention, poor nutrition and fatigue, their mood at the time and their willingness to perform spirometry. Cooper et al, stress that individual variability was consistent and that assessment of significant change could be made more accurately by predetermining the variability of that individual rather than group data. However it remains the best available tool at this present time.

Sputum weight, whether dry or wet, has always been a controversial outcome measure in physiotherapy research because of wide intra- and inter-subject variability. Age and weight of the patient will also influence the volume of sputum produced and, in ventilated patients, volume of instilled saline will influence sputum recovery. Dry sputum weight is considered to demonstrate greater reliability than wet sputum weight.

Some studies dispute the correlation between the amount of sputum and improved respiratory function in ventilated patients (Mackenzie et al, 1989; Hasani et al 1994) while others suggest that sputum clearance is associated with an improvement in respiratory function (Cochrane et al, 1977). Many studies to date which used sputum weight as an outcome measure have been undertaken in non-ventilated patients, but a recent study found that total respiratory system compliance (C_{rs}) and sputum clearance were improved by the addition of manual hyperinflation to a physiotherapy treatment of positioning and suctioning in mechanically ventilated patients (Hodgson et al, 2000). Sputum, however, remains a useful adjunct to other measures of respiratory function and is an accessible measure of treatment success in individual patients, especially in the absence of dramatic changes on chest radiograph or auscultation.

Future outcome measures may include the multiple breath washout technique (MBW) from which Lung clearance index (LCI) can be derived. This relatively new tool measures ventilation inhomogeneity, which is considered to be a very sensitive means of detecting changes in small airway function (Aebischer and Kraemer, 1993;

Gustafsson et al, 2003). This test is not dependent on patient effort and can also be done in small children who cannot yet perform FEV₁ spirometry.

Pain scores should have been measured and documented from the start of this study as there was a subjective/verbal trend for this to be the major factor in the sub-optimal performance of spirometry in the 24-hour period post-surgery. Adequate analgesia may also have substantial implications for effective huffing and coughing during physiotherapy airway clearance manoeuvres post-surgery.

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6.10 Recommendations for clinical practice and future studies

If intra-operative physiotherapy is considered necessary, it may be required that the anaesthetist increases V_T or PEEP to counteract any short-term negative effects of physiotherapy.

Pain management was subjectively identified as an aspect that interferes with optimal post-operative spirometry. It would be useful to do a study using pain scores to identify how the patient is responding to the analgesia and in terms of physiotherapy treatment, whether it is adequate in assisting of pain relief for coughing and mobilization. A protocol for analgesia immediately post-surgery would ensure that all patients receive optimal management with regular assessment by the 'pain team'.

If a sputum specimen is required for microbiology and verification of antibiotic cover, physiotherapy treatment in theatre is indicated, particularly for patients who do not expectorate.

Physiotherapy treatments are effective in clearing a large amount of sputum and are beneficial for patients who have large amounts of retained secretions. Careful planning and liaison with the surgeons and anaesthetists is essential to ensure that sufficient time is provided on the theatre list should the patient require physiotherapy.

Further research on this topic would be valuable in identifying which patients would benefit from physiotherapy treatments in theatre. Evaluation of individual components of treatment or a combination of factors may be useful in identifying the respective effects on respiratory mechanics.

CHAPTER 7 CONCLUSION

The study has evaluated the immediate and post-operative effects of physiotherapy treatments on lung function parameters in patients with CF in theatre and the requirement for physiotherapy in the immediate post-operative period. These treatments are routine clinical practice despite minimal clinical evidence. The 'CO₂SMO Plus' was found to be a reliable, safe and useful tool in measuring respiratory mechanics in the anaesthetic room. Mean R_{rs} increased and C_{rs} reduced significantly following physiotherapy. The short-term deterioration in respiratory mechanics immediately following physiotherapy under anaesthesia was an unanticipated result. This acute deterioration in respiratory function was not a sustained effect. FEV₁ was reduced in both physiotherapy and control group at the 24-hour post-surgery measurement compared to the pre-surgery value but this was not statistically significant. The lower FEV₁ may be explained by the subjective reporting of pain from the surgical site by the patient to the lung function technicians. A moderate to large amount of sputum were cleared during the physiotherapy treatments in six of the eight patients which decreases the risk of airway obstruction and mobilises secretions facilitating ease of expectoration post-operatively. There was no increased requirement for physiotherapy post-surgery in both groups. One would need to consider the assumed benefits from removal of secretions and the acute deterioration of respiratory function in deciding whether to perform physiotherapy in children with CF undergoing a general anaesthesia. This study has some unanswered questions for the acute deterioration in lung function and the varied individual responses to physiotherapy treatment. Further study is required to investigate factors that influence these individual responses to therapies.

APPENDIX A: INFORMATION SHEET FOR PARENTS/GUARDIANS

DOES PHYSIOTHERAPY IN ANAESTHETISED CHILDREN WITH CYSTIC FIBROSIS IMPROVE POST OPERATIVE LUNG FUNCTION?

Thankyou for taking the time to read this information leaflet. We would like to ask your permission to include your child in this project. This study is being carried by Esta-Lee Tannenbaum, Eleanor Main, Ammani Prasad, Dr Robert Dinwiddie and Dr Colin Wallis at Great Ormond Street Children's Hospital.

The aim of the study

Physiotherapy treatments are often performed during a general anaesthetic for an elective surgical procedure such as a gastrostomy or portacath insertion. This is because we believe they help to clear secretions and improve the post-operative period when patients may be less able to comply with treatment due to pain and discomfort. But we do not know if these treatments are better then routine suction by the anaesthetist. We would like to look in detail at the effects of these physiotherapy treatments using lung function test measurements.

How is the study being done?

Your child has been admitted for a surgical procedure. Using a computer programme, your child will be selected into either a physiotherapy treatment or routine care by the anaesthetist. On the day of surgery he/she will perform similar lung function tests (if age appropriate) to the ones which they commonly perform at CF clinic. Immediately before theatre but after your child has been anaesthetised a small monitor will be attached to the ventilator tubing measuring airflow in the lungs. This will take approximately 5 minutes. Physiotherapy treatment or suctioning by the anaesthetist will then be performed to clear secretions from the lungs. Following this the small monitor will again measure airflow in the lungs. The total extra time required for these measurements will be 10-15 minutes. When your child has returned from theatre and is in the ward, lung function tests will be carried out at approximately 6 and 24 hours after the surgery. All routine care (including physiotherapy) for your child will continue as normal.

What are the risks and discomforts?

We do not anticipate that this study is associated with additional risks or discomforts. This project has been approved by an independent research ethics committee who believe that it is of minimal risk to your child. Although the anaesthetic time is slightly increased (10-15minutes) this is considered to be of minimal risk.

What are the potential benefits?

This study will enable us to be sure as to whether or not physiotherapy treatments performed whilst children with cystic fibrosis are having an anaesthetic are helpful and safe. It will help with the future management of cystic fibrosis patients in the best possible way.

Who will have access to the research record?

Patients will not be identifiable on recorded data which in any case will only be available to the researchers and will be completely confidential.

Does my child have to take part in this study?

If you decide now or even at a later stage that you do not wish to participate in this research project, that is entirely your right and will not in any way prejudice any present or future treatment.

Who do I speak to if problems arise?

If you have any complaints about the way in which this research project has been, or is being conducted, please in the first instance discuss them with either of the researchers. If the problems are not resolved, or if you wish to comment in any other way, please contact the Chairman of the Research Ethics Committee. This can be done by post, via the Research and Development Office, The Institute of Child Health, 30 Guilford Street. London WC1N 1EH. If urgent you can telephone on 020 7242 9798 extension 2620 and the committee administrator will put you in contact with him.

Details of how to contact the researchers:

Esta-Lee Tannenbaum: Phone 020 7405-9200 (bleep 464)

Eleanor Main: Phone 020 7405-9200 ext 5424

Ammani Prasad: Phone 020 74059200 ext 2328

Dr Robert Dinwiddie and Dr Colin Wallis: 0207405922 ext 5453

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APPENDIX B : INFORMATION SHEET FOR THE PATIENT

DOES PHYSIOTHERAPY IN ANAESTHETISED CHILDREN WITH CYSTIC FIBROSIS IMPROVE POST OPERATIVE LUNG FUNCTION?

Thankyou for taking the time to read this information leaflet. We would like to ask your permission to include your child in this project. This study is being carried by Esta-Lee Tannenbaum, Eleanor Main, Ammani Prasad, Dr Robert Dinwiddie and Dr Colin Wallis at Great Ormond Street Children's Hospital.

The aim of the study

Children with cystic fibrosis sometimes need to be admitted to hospital for a routine operation (e.g. Portacath or gastrostomy). This requires you to be put to sleep (called a general anaesthetic).Physiotherapy treatment is then performed because we believe they help to clear secretions from your lungs and make the recovery from the operation easier. However, it has not been proven that doing these physiotherapy treatments is better than having no treatment during anaesthesia. We would like to look in detail at the effects of these physiotherapy treatments using lung function tests.

How is the study being done?

When you are admitted for the operation, you will be randomly selected either to receive physiotherapy treatment during your anaesthetic or not. On the day of the operation you will perform lung function tests just like those at CF clinic. Immediately before the operation but after you are asleep a small monitor will measure air flow in your lungs for approximately 5 minutes. Physiotherapy treatment by a physiotherapist or routine care by the anaesthetist will then be performed to clear secretions from your lungs. Following this we well again measure the air flow in your lungs for another 5 minutes, so in total you will be asleep for an extra 10-15 minutes.

When you had had your operation and are back on the ward you will be asked to repeat the normal lung function tests about 24 hours after the operation. All routine care (and physiotherapy) will continue as normal.

What are the risks and discomforts?

We do not anticipate that this study is associated with additional risks or discomforts. This project has been approved by an independent research ethics committee who believe that it is of minimal risk to you. The time that you will be asleep is only slightly increased (10-15 minutes) and is considered to be of minimal risk.

What are the potential benefits?

This study will help us to be sure as to whether or not physiotherapy treatments performed whilst children with cystic fibrosis are having an anaesthetic are helpful and safe. It will help with the future management of cystic fibrosis patients in the best possible way.

Who will have access to the research record?

Patients will not be identifiable on recorded data which in any case will only be available to the researchers and will be completely confidential.

Does my child have to take part in this study?

If you decide now or even at a later stage that you do not wish to participate in this research project, that is entirely your right and will not in any way prejudice any present or future treatment.

Who do I speak to if problems arise?

If you have any complaints about the way in which this research project has been, or is being conducted, please in the first instant discuss them with either of the researchers. If the problems are not resolved, or if you wish to comment in any other way, please contact the Chairman of the Research Ethics Committee. This can be done by post, via the Research and Development Office, The Institute of Child Health, 30 Guilford Street. London WCIN 1EH. If urgent you can telephone on 020 7242 9798 extension 2620 and the committee administrator will put you in contact with him.

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APPENDIX C: PROTOCOL

1. Within a 24 hour period prior to surgery all patients (who are able to) will perform routine spirometry to measure pre-operative lung function.
2. Immediately following induction of anaesthesia, intubation and stabilization of the patient the 'CO₂SMO Plus' sensor is attached between the endotracheal tube (ETT) and the ventilator circuit. The anaesthetist is asked to use a cuffed ETT and to maintain as small a leak as possible.
3. 'CO₂SMO Plus' lung function measurements are recorded for a 5 minute period.
4. Ventilator settings should remain unchanged during the 'CO₂SMO Plus' measurements before and after the physiotherapy or control treatment, if clinically feasible.
5. The monitoring system is then disconnected from the circuit.
6. The patient will then receive either a physiotherapy treatment or anaesthetic care in the control group.
7. Physiotherapy treatment: Physiotherapy treatment is commenced by a senior physiotherapist. Treatment comprises a combination of positioning, saline instillation, manual hyperinflation - an emphasis on inspiration, a pause at end inspiration followed by a quick release of the bag during which time expiratory vibrations are applied to the chest wall. ETT suction is undertaken after secretions are mobilised by the above technique. This procedure is repeated until the clinical physiotherapist feels that sufficient mucus clearance has been obtained. All treatment details are carefully recorded.
8. Control – No intervention from the physiotherapist: These patients are under the care of the anaesthetist. No formal protocol is given to the anaesthetist – they are to use their clinical judgement as to whether to carry out manual hyperinflation and suction or no intervention.

9. Vital signs (blood pressure, heart rate and oxygen saturation) will be monitored throughout the Group A or B period. The physiotherapy treatment will as per usual practise be discontinued if any adverse changes in vital signs are noted.
10. Immediately following either Group A or B the 'CO₂SMO Plus' is re-attached to the ventilator circuit and lung function measurements made for a further 5 minutes.
11. Ventilator settings are to remain constant throughout (if clinically feasible).
12. The patient then undergoes the surgical procedure.
13. The post operative course for the patient continues as per the normal care plan on the ward (regular observations of blood pressure, oxygen saturation, heart rate and respiratory rate. All medicines are given as charted on the medicine sheet).
14. The requirement for physiotherapy (frequency and duration) is recorded in the 24-hour period post-surgery.
15. Spirometric lung function measurements are repeated within 24-hours post-operatively.
16. The respiratory technicians performing the spirometry are blinded as to what treatment the patient received in theatre.

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