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Chest Physiotherapy During Anesthesia for Children With Cystic Fibrosis: Effects on Respiratory Function

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Summary. Background: Physiotherapists sometimes use elective surgical procedures for children with cystic fibrosis as an opportunity to perform physiotherapy treatments during anesthesia. These treatments theoretically facilitate direct endotracheal airway clearance and compensate for any post-operative respiratory deterioration related to the anaesthetic and surgery. Materials, patients, and methods: Children were randomized either to receive physiotherapy or not following anesthesia and intubation. Respiratory mechanics (C_{rs} and R_{rs}), tidal volume, and peak inspiratory pressure (PIP) were measured immediately before and after physiotherapy. FEV_1 was measured before and after surgery and post-operative physiotherapy requirements were recorded. Results: Eighteen patients, mean age 12 years (range 2.8–15 years) were recruited, with nine in each group. Both groups showed a non-significant decline in FEV_1 the day after surgery compared with pre-operative values (−5.8%: physiotherapy and −7.1%: control). Both PIP and R_{rs} increased significantly following physiotherapy (within- and between-groups, $P < 0.05$). In addition, there was a significant within-group reduction in C_{rs} after physiotherapy which approached significance between-groups ($P = 0.07$). There were no significant within- or between-group differences in tidal volume following treatment in either group. Conclusion: The unanticipated decline in respiratory function immediately following physiotherapy was short-lived and not discernible in longer term outcomes measured by FEV_1 or physiotherapy requirements post-operatively. If respiratory physiotherapy under anesthesia is considered necessary and the benefits of removing secretions are deemed to outweigh the short-term risks, it may be necessary for the anaesthetist to consider modifying ventilatory support to counteract any short-term negative effects of the treatment. **Pediatr Pulmonol. 2007; 42:1152–1158.**

Key words: physical therapy; cystic fibrosis; general anesthesia; respiratory function tests; pediatrics; respiratory therapy.

INTRODUCTION

Median survival in cystic fibrosis (CF) has increased progressively over the past 30 years as a result of improved therapies and a co-ordinated multi-professional approach to care.[1] Physiotherapy airway clearance techniques are considered an integral part of the care package for children with CF.

Children with CF are periodically admitted to hospital for minor elective surgical procedures and physiotherapists in some centers use these elective surgical procedures as an opportunity to perform physiotherapy treatments, while the child is intubated and under general anesthesia (GA).

The rationale for such treatments is that effective airway clearance during anesthesia will compensate for any post-operative respiratory deterioration related to the anaesthetic and surgery, or compromised airway clearance techniques because of post-operative discomfort. In

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addition, bronchial lavage and suction during anesthesia can provide valuable sputum samples for microbiological culture, especially in children reluctant or unable to expectorate.

Relatively little is known about the immediate or post-operative effects of physiotherapy treatments under anesthesia and the evidence base for these interventions remains limited.[2,3] The aim of this study was to evaluate the immediate and longer term effects of physiotherapy treatments under anesthesia in children with CF compared with a control group. Primary outcomes were changes in respiratory function. Immediate (intra-operative) effects of physiotherapy under anesthesia were measured in terms of changes in respiratory compliance (C_{rs}), peak inspiratory pressure (PIP), respiratory resistance (R_{rs}), and tidal volume (V_{TE}). Longer-term effects were assessed by pre- and post-operative values of forced expiratory volume in 1 sec (FEV_1). Physiotherapy requirements in the immediate post-operative period were also recorded.

METHODS

Inclusion Criteria

Children with confirmed CF (positive sweat test and/or genotype) who required elective surgery at Great Ormond Street Hospital for Children NHS Trust (a specialist CF center) were eligible to participate in the study. Children requiring thoracic surgery, for example lobectomy, were excluded. The study was reviewed and approved by the Institute of Child Health and Great Ormond Street Hospital's Local Research Ethics Committee. Parents (or careers) provided written informed consent for participation and children were invited to provide assent to taking part in the study.

Equipment

FEV_1 was measured using a standard spirometer (Jaeger Masterscreen version 4.3).

Respiratory function measurements under anesthesia were obtained using the CO_2SMO® Plus! Respiratory Profile Monitor (Respironics, Wallingford, CT). This portable device is attached within the ventilator circuit, proximal to the endotracheal tube (ETT) and provides accurate and reliable, non-invasive measurements of respiratory function in ventilated children.[4,5] A time-cycled modality was used to ventilate patients during all surgical procedures.

Protocol

Participants were randomized into two groups using a minimization software program, with stratification for FEV_1, age, and sex. The investigator who enrolled subjects remained unaware of treatment group allocations until after each subject was enrolled. Lung function technicians undertaking FEV_1 measurements were blinded to treatment group allocation. The treatment group received respiratory physiotherapy treatment under anesthesia (before the surgical procedure) although the control group received standard respiratory support from the anaesthetist. Duration of physiotherapy and specific techniques were not standardized, as this would have precluded evaluation of normal physiotherapy practice. Treatment details, in accordance with standard clinical practice at our hospital, were determined by the therapist performing the treatment and influenced by factors including amount of sputum during the treatment, tolerance of the procedure, and ongoing re-assessment by auscultation and observation.

FEV_1 was measured within 24 hr before surgery and again the day after surgery. In addition, FEV_1 data were retrieved from the most recent clinic visit preceding admission (within 3 months) and the first clinic visit following surgery (within 3 months).

After anaesthetic induction, participants were routinely intubated using a cuffed ETT to ensure minimal tracheal tube leak. A flow sensor was connected within the ventilator tubing to the CO_2SMO® Plus! respiratory monitor. Baseline measures of C_{rs}, PIP, R_{rs}, and V_{TE}, were recorded continuously for 5 min before and after physiotherapy in the treatment group and standard care in the control group. Ventilator settings were kept constant before and after physiotherapy, to facilitate comparison of lung function measurements. Data obtained from the CO_2SMO were electronically collected and not subject to investigator bias or patient effort or co-operation.

Following baseline measurements in the treatment group, the CO_2SMO® Plus! was detached to prevent contamination of the sensor from tracheal secretions. Chest physiotherapy then commenced, with treatment duration and specific techniques varying according to clinical requirements. Treatments typically included modified postural drainage (without head-down tipping), saline instillation, manual lung hyperinflation with expiratory chest wall vibrations and tracheal tube suction. Manual lung hyperinflation was performed using a 500 ml reservoir bag for infants and a 1 L bag for older children, with an inspired oxygen fraction (FiO_2) of 1.0. Treatment continued until the physiotherapist felt that mucus clearance had satisfactorily been achieved. Treatments were performed by a senior specialist physiotherapist. All treatment details were recorded and immediately following treatment the CO_2SMO® Plus! was re-attached and measurements repeated for a further 5 min.

Following baseline measurements in the control group, physiotherapy was not performed and airway clearance procedures were left to the discretion of the anaesthetist. If no intervention was felt to be necessary, measurements were continued for a further 5 min. Previous studies at this hospital have shown that

disconnection and reconnection of the sensor alone had negligible effects on measurements.[6]

All participants received at least one chest physiotherapy treatment before being taken to surgery and were then assessed by a specialist physiotherapist within 1 hr of returning to the ward. Physiotherapy requirements were determined by the therapist on duty from assessment of clinical signs, oxygen requirements, auscultation, amount of sputum expectoration, and mobility. The number of chest physiotherapy treatments required in the 24-hr post-operative period was recorded for both groups.

Analysis

Data were analyzed using SPSS statistical software (version 13.0). Statistical analysis of data was not undertaken by the physiotherapist performing treatments. Descriptive analysis was undertaken for demographic and baseline data. Normal data distribution could not be assumed and non-parametric tests were selected to compare groups. The Wilcoxon signed-rank test was used to assess and compare measurements of FEV_1, C_{rs}, PIP, R_{rs}, and V_{TE} before and after surgery or treatment. The Mann–Whitney *U*-test was used to compare differences between groups.

RESULTS

Data were collected between June 2000 and April 2002. Eighteen participants (10 female), median age 12 years (range 2.8–15 years) were recruited to the study. All but two participants were admitted approximately 1 week prior to surgery for pre-operative intravenous antibiotic therapy. The two not requiring pre-operative antibiotic cover—one in each group—were both clinically well ($FEV_1 > 75\%$ predicted) prior to polypectomy. Baseline demographic data and surgical details for both groups are shown in Table 1.

FEV_1 data were obtained before and after surgery in 17 participants (one child was 3 years old and unable to perform spirometry satisfactorily). Baseline FEV_1 values were higher in the physiotherapy group.

Following early pre-surgical admission for antibiotic therapy, there was a significant improvement in FEV_1 in the control group between the final clinic visit prior to admission and the day before surgery (Table 2: mean difference 5.2%, 95% CI: 0.78 to 9.67, $P < 0.05$). There was no significant difference in FEV_1 between the last clinic visit and the day before surgery in the physiotherapy group (mean difference 2.3%, 95% CI: −6.2 to 10.7) or between groups (mean difference 3.0%, 95% CI: −6.0 to 11.9). Both groups showed a decline in FEV_1 the day after surgery compared with immediate pre-operative values. This decline was not statistically significant within or between groups (−5.8%, 95% CI: −13.4 to 1.9 for physiotherapy, −7.1%, 95% CI −15.9 to 1.6 for the control group and 1.4%, 95% CI: −12.1 to 9.4 between groups). There were no significant within or between group differences in FEV_1 between the last clinic visit prior to surgery and the first clinic visit following surgery (Table 2).

Respiratory function measurements under anesthesia (C_{rs}, PIP, R_{rs}, and V_{TE}) were analyzed in 16 of the 18 participants. Two participants—one in each group—were excluded from analysis. One participant in the treatment group had a tracheal tube leak exceeding 20% during measurements.[7] The other participant in the control group suffered a sudden tracheal tube mucous obstruction immediately following intubation. The anaesthetist requested emergency physiotherapy treatment which precluded baseline measurements and data could not be collected.

In the remaining participants, there was a significant increase in PIP and R_{rs} and reduction in C_{rs} immediately following physiotherapy (Table 3). Between-group differences were significant for PIP and R_{rs} ($P < 0.05$) and approached significance for C_{rs} ($P = 0.07$). There was a small but significant increase in PIP in the control group with no significant changes in C_{rs} or R_{rs} (Table 3). There

TABLE 1—Demographic Data for Physiotherapy and Control Groups

	Physiotherapy (n = 9)	Control (n = 9)
Median age in years (range)	11.3 (3–15)	12 (6–15)
Median weight in kg (range)	41 (14.5–61)	46.5 (18–61.3)
Gender, M:F	4:5	4:5
Disease severity		
$FEV_1 > 70\%$	2	0
FEV_1 50–70%	6	5
$FEV_1 < 50\%$	0	4
Surgery		
Portacath insertion (n = 13)	7	6
Polypectomy (n = 2)	1	1
Gastrostomy insertion	0	1
Oesophageal dilatation	0	1
Cataract removal	1	0
Median length of anesthesia in minutes (range)	100 (70–130)	85 (45–200)

TABLE 2— Pre- and Post-Operative FEV_1 for Physiotherapy and Control Groups

	FEV_1 at clinic visit before surgery	FEV_1 24 hr before surgery	FEV_1 24 hr after surgery	FEV_1 at clinic visit after surgery
Physiotherapy (n = 8)	67.4 (13.8)	69.0 (9.5)	63.3 (15.6)	61.8 (19.5)
Control (n = 9)	53.9 (19.0)	58.2 (15.9)	51.1 (11.4)	58.0 (20.9)

FEV_1 data are expressed as mean % predicted (standard deviation).

were no significant within- or between-group differences in V_{TE} following treatment in either group.

In the treatment group, mean duration of physiotherapy was 11.4 min (range 10–15 min) and the average amount of saline instilled was 0.5 ml/kg (range 0.25–0.64 ml/kg).

Moderate volumes of sputum were retrieved during endo-tracheal suction in six of eight patients (0.15 ml/kg: range 0.07–0.27 ml/kg) and sputum samples were retrieved for all patients in the physiotherapy group for microbiological culture. Medical management was changed on the basis of these cultures in only one of the patients, in whom the sample demonstrated growth of Pseudomonas aeruginosa which was not isolated prior to surgery. None of the children in the control group received any form of airway clearance and sputum samples were not retrieved.

Participants had an average of 3 treatments (physiotherapy) and 3.6 treatments (control) in the 24 hr period following surgery, which was not statistically significant. There were no differences in length of stay between groups, and all patients received post-operative intravenous antibiotics until the day of discharge home.

DISCUSSION

This study was the first of its kind to explore the immediate effects of physiotherapy under anesthesia in children with CF and exposed an unanticipated acute deterioration in lung function in participants receiving treatment. Results demonstrated a reduction in C_{rs} and an increase in PIP and R_{rs} immediately following physiotherapy during anesthesia, while such changes were not observed in the control group. Significant between-group differences in PIP and R_{rs} with a tendency for significant difference in C_{rs} suggested that these results were unlikely to have occurred by chance. This acute deterioration in respiratory function was however not reflected in longer-term outcomes measured by FEV_1 or physiotherapy requirements post-operatively.

The increase in PIP was coupled with deterioration in C_{rs} in the physiotherapy group. The use of a time-cycled modality for all participants meant the ventilator was set to deliver air for a preset duration during each breath cycle, allowing airway pressure to vary as a product of lung mechanics. Typically, a consistent tidal volume was delivered by change in flow during the time cycle. In the presence of worsening C_{rs}, the ventilator increases flow to maintain tidal volume within the set inspiratory time (at the expense of airway pressure) and therefore PIP increases simultaneously to maintain tidal volume. Both the decline in C_{rs} and the increase in PIP following physiotherapy confirmed the acute reduction in respiratory mechanics as a result of the intervention. Mechanisms for this effect in the treatment group are unclear. No changes in C_{rs} occurred in the control group and the magnitude of change in PIP was minimal, so it must be assumed that these changes were related specifically to physiotherapy treatment. Although some studies document an improvement in C_{rs} following physiotherapy,[8,9]

TABLE 3— Respiratory Function Measurements During Anesthesia

Parameter	Before intervention[1] (B)	After intervention[1] (A)	95% CI (A − B)	*P*-value
C_{rs} (ml/cm H_2O/kg)				
Physiotherapy	0.8 (0.3)	0.6 (0.1)	−0.33 to −0.01	0.02
Control	0.7 (0.1)	0.7 (0.1)	−0.3 to 0.3	0.89
PIP (cm H_2O)				
Physiotherapy	21.9 (3.4)	25.4 (3.9)	+0.3 to 6.6	0.03
Control	21.1 (6.4)	21.8 (6.5)	−0.1 to 1.5	0.05
R_{rs} (cm H_2O/L/sec)				
Physiotherapy	19.7 (7.8)	26.3 (10.8)	−0.42 to 13.5	0.05
Control	20.9 (6.9)	21.0 (5.1)	−2.1 to 2.1	0.26
V_{TE} (ml/kg)				
Physiotherapy	10.5 (2.9)	9.6 (2.1)	−2.6 to 0.87	0.40
Control	8.4 (2.0)	8.6 (1.9)	−0.41 to 0.92	0.78

[1]Data expressed as mean (standard deviation).

others report no change or even deterioration.[10] Application of a negative suction pressure has also been associated with alveolar collapse and a reduction in C_{rs}.[11,12] The use of manual hyperinflation between suction procedures would however be expected to compensate for loss of compliance caused by negative suction pressure.[13]

The observed increase in R_{rs} is difficult to explain. In general, R_{rs} measured at the airway opening is likely to reflect the resistance generated by the upper airways as these represent the narrowest cross-sectional area for airflow. It would be reasonable to expect that removing secretions from the upper airways during suction would reduce R_{rs} measured at the airway. In a previous study involving ventilated children with acute respiratory pathology, physiotherapy treatments involving removal of significant amounts of mucus were associated with a reduction in R_{rs}.[6] Children with CF may not be a comparable population because the depth and magnitude of excess pulmonary mucus extends throughout the broncho-alveolar architecture rather than being limited to the large conducting airways. Physiotherapy treatments, including manual hyperinflation, chest wall vibrations and suction may, while clearing substantial amounts of secretions from the upper airways, also serve to mobilize and redistribute peripheral secretions. Retrieval of even large volumes of mucous from the upper airways will not necessarily mean the lungs are ''clear.'' Redistribution and proximal movement of both central and peripheral secretions may have the overall effect of increasing R_{rs} as a result of disrupting ventilation homogeneity or the fragile equilibrium of regional ventilation.

Other explanations for the increase in R_{rs} include response to saline instillation and suction. The instillation of saline during physiotherapy may have contributed to airway reactivity and bronchoconstriction.[14,15] However, endotracheal instillation of normal saline is widely used and such effects have not been observed in other populations.[16,17] Endotracheal suction has also been associated with bronchospasm and falls in oxygen saturation but again has not been a consistent finding in other ventilated pediatric populations.[18] This acute decline in lung function provides an interesting dilemma for therapists: will the benefit of clearing upper airway secretions under anesthesia outweigh the risks of potential short-term deterioration?

FEV_1 data were collected during the clinic visit prior to admission (within 3 months of surgery) in order to address concerns that pre-operative antibiotic therapy may have produced a misleading elevation in the pre-operative baseline FEV_1 levels. The control group alone had a significant increase in FEV_1 between the two pre-operative measures, but this did not appear to influence changes post-operatively in a disproportionate way. There was substantial within-subject variability of FEV_1 values in this pediatric population, reflecting the fact that FEV_1 can be an unreliable measure in children because it depends on effort and cooperation.[19]

The decline in FEV_1 within 24 hr of surgery was similar in both groups (although statistically non-significant). The acute deterioration observed in the treatment group during anesthesia was therefore short-lived and not reflected by important changes in respiratory function after surgery. The small decline in FEV_1 may have been due to post-operative discomfort and/or some residual effects of GA.[20,21] The deleterious effects of GA on lung function have been well described, although the use of modern anaesthetic agents and ventilation modalities has reduced the morbidity associated with anesthesia.[22] The control group demonstrated a lower baseline FEV_1 before surgery and may have been predicted to be more vulnerable to the deleterious effects of anesthesia and surgery. However, the decline in FEV_1 post-operatively was not proportionately larger in this group.

A moderate amount of sputum was cleared from six participants in the physiotherapy group. The value of sputum volume as an outcome measure in physiotherapy trials is contentious due to 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 characterized by copious sputum production. Copious secretions were cleared from the patient in the control group who was excluded from analysis because they required urgent physiotherapy treatment immediately following intubation. In this instance removal of secretions was clearly beneficial. The evidence for beneficial effects of physiotherapy in the presence of copious secretions and total or partial alveolar collapse is reasonably convincing.[23]

Interpreting the results of this study in terms of clinical practice poses a challenge. On one hand removing pulmonary secretions from children with CF is considered important in principle. On the other hand an acute deterioration in lung function peri-operatively gives cause for concern. It may be that in individual children, the risks of a short-term deterioration in lung function are outweighed by the potential benefits of removing airway secretions. No patients in the physiotherapy group had severe lung disease. It is possible that the benefits of removing secretions under anesthesia would be more apparent in children with more severe disease.

A small but additional benefit of physiotherapy during anesthesia is the opportunity to obtain a good sample for microbiological culture, particularly in children who are unable to expectorate. This may be helpful in guiding appropriate antibiotic therapy and was clearly beneficial for the participant in this study who had identification of, and subsequent treatment for Pseudomonas aeruginosa infection. Despite recommendations that chest physiotherapy

and suctioning should precede arousal from anesthesia and extubation in patients with CF, none in the control group received such interventions.[24]

The duration of anesthesia was on average 15 min longer in the group receiving physiotherapy which reflected the time needed to perform the treatment. The extended anaesthetic time had no obvious deleterious consequences in terms of either decline in FEV_1 or number of physiotherapy treatments required post-operatively. Patients in both treatment and control groups received a similar number of physiotherapy treatments in the 24-hr period following surgery. These findings are comparable with a study by Wordsworth et al. (1996)[3] who reported the physiotherapy treatment time in the 2 days following surgery were not significantly different in a control group compared with a group receiving bronchial lavage during anesthesia.

Potential bias in this study was minimized by blinding lung function technicians to treatment group allocation and ensuring statistical analysis was not undertaken by the physiotherapist performing treatments. Data obtained from the $CO_2SMO^{®}$ Plus! respiratory monitor were electronically collected and not subject to investigator bias or patient effort or co-operation. The fact that the physiotherapist doing the treatments was aware of the allocation was less likely to have created a bias than the fact that all treatments were performed by one therapist.

This was a small study and results should be therefore interpreted with caution. Retrospective power calculations were done, which were not feasible prior to the study, because data from similar studies were not available. These indicated that this study had statistical power between 65% and 70% to detect differences between groups at a 10% confidence level for all outcomes. Eleven participants in each group would have increased the statistical power to at least 80% for all outcomes. However, even in this limited population, there was evidence of a significant short-term deterioration in respiratory function after physiotherapy under anesthesia. Some questions remain with respect to the cause of this and the variable individual response to physiotherapy treatment. Further research, identifying which children would be likely to benefit from physiotherapy treatments in theatre would be valuable. Evaluation of individual components of treatment or specific treatment performance may be useful in identifying the respective effects on respiratory mechanics.[25]

CONCLUSION

This study is the first of its kind to evaluate both the immediate and post-operative effects of physiotherapy treatments under anesthesia in children with CF. Results provided evidence of acute deterioration in lung function demonstrated by changes in C_{rs}, PIP and R_{rs}, following physiotherapy that were not observed in the control group. This deterioration was short-lived and was not discernible either in FEV_1 values post-operatively or in a requirement for extra physiotherapy support following surgery. Therapists should consider whether the perceived benefit from removing secretions outweighs the potential for short-term deterioration in individual children with CF undergoing a GA. If physiotherapy treatment under anesthesia is considered necessary and the benefits of such an intervention are deemed to outweigh the risk (there may be copious secretions or a specimen is required for microbiology), it may be recommended that the anaesthetist modifies ventilation to counteract any short-term negative effects of physiotherapy.

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