

**STANDARDS OF CARE AND GOOD
CLINICAL PRACTICE FOR THE
PHYSIOTHERAPY MANAGEMENT
OF CYSTIC FIBROSIS**



**Association of
Chartered
Physiotherapists in
Cystic Fibrosis
(ACPCF)**

June 2011

Second Edition

EDITORIAL BOARD

Chairs

Penny Agent	Deputy Director of Rehabilitation & Therapies Royal Brompton & Harefield NHS Foundation Trust, London
Lisa Morrison	Clinical Specialist Physiotherapist Gartnavel General Hospital, Glasgow
Ammani Prasad	CF Co-ordinator, Senior Research Physiotherapist Great Ormond Street Hospital, London

Contributors

Penny Agent	Royal Brompton & Harefield NHS Foundation Trust, London
Cathy Bindoff	Royal Brompton & Harefield NHS Foundation Trust, London
Judy Bradley	University of Ulster & Belfast Health and Social Care Trust, City Hospital, Belfast
Tracey Daniels	York Teaching Hospital Foundation NHS Trust, York
Emma Dixon	Royal Brompton & Harefield NHS Foundation Trust, London
Elaine Dhouieb	Royal Hospital for Sick Children, Edinburgh
Katie Ferguson	King's College Hospital NHS Foundation Trust, London
Georgie Housley	Royal Brompton & Harefield NHS Foundation Trust, London
Lisa Kent	Belfast Health and Social Care Trust, City Hospital, Belfast
Nicola Mills	University Hospitals of Leicester, Leicester
Gemma Morgan	Royal Brompton & Harefield NHS Foundation Trust, London
Lisa Morrison	Gartnavel General Hospital, Glasgow
Helen Parrott	Royal Brompton & Harefield NHS Foundation Trust, London
Ammani Prasad	Great Ormond Street Hospital, London
Cathy Sandsund	Royal Marsden NHS Foundation Trust, London

Acknowledgements

Special thanks to the Cystic Fibrosis Trust, and to the many physiotherapists and other members of the CF multidisciplinary teams who contributed to and supported the formulation of these guidelines.

CONTENTS

I. FOREWARD

- 1.1 Document development
- 1.2 How to use this document
- 1.3 Review of the document
- 1.4 Grading scheme for recommendations

2. PHYSIOTHERAPY NATIONAL STANDARDS OF CARE FOR PEOPLE WITH CYSTIC FIBROSIS (2009)

- 2.1 How to use standards
- 2.2 Introduction
- 2.3 Definition of “Specialist CF Physiotherapist”
- 2.4 Physiotherapy standards

3 OUTCOME MEASURES

- 3.1 Airway clearance
- 3.2 Exercise testing
- 3.3 Other outcome measures

4 AIRWAY CLEARANCE TECHNIQUES

- 4.1 Active cycle of breathing techniques
- 4.2 Autogenic drainage
- 4.3 Positive expiratory pressure
- 4.4 Oscillatory devices
 - Flutter®
 - Acapella
 - Cornet
 - Extra-thoracic oscillations (High frequency chest wall oscillation)
- 4.5 Intra-pulmonary percussive ventilation
- 4.6 Postural drainage
- 4.7 Intermittent positive pressure breathing

5 EXERCISE

- 5.1 Introduction
- 5.2 Evidence for physical training
- 5.3 Risks associated with specific exercise
- 5.4 Exercise testing

6 MUSCULO-SKELETAL PROBLEMS AND POSTURAL MANAGEMENT

7 INHALATION THERAPY

- 7.1 Introduction
- 7.2 Nebuliser devices
- 7.3 Timing of medications
- 7.4 Adherence

8 NON-INVASIVE THERAPY

- 8.1 Introduction
- 8.2 NIV for airway clearance
- 8.3 NIV for exercise
- 8.4 NIV for respiratory failure
- 8.5 NIV for nocturnal hypoventilation

9 MANAGEMENT OF SPECIFIC ISSUES

- 9.1 Urinary incontinence
- 9.2 Pregnancy
- 9.3 Liver disease
- 9.4 Haemoptysis
- 9.5 Pneumothorax
- 9.6 Critical care
- 9.7 Post bi-lateral lung transplant
- 9.8 End-stage disease and end of life care

10 REFERENCES

11 GLOSSARY OF ABBREVIATIONS

12 APPENDICES

Appendix I: Physiotherapy Guidance Paper: Physiotherapy Management of Screened Infants with CF (2008)

- Appendix Ia Parent Assessment Tool
- Appendix Ib Physical activity in infants
- Appendix Ic Airway clearance techniques

Appendix II: Exercise tests available

I. FOREWARD

I.1 Document development

This document has been developed primarily as an update to the previous ‘Clinical Guidelines for the Physiotherapy Management of Cystic Fibrosis’ (2002). It also includes the ACPCF/CF Trust endorsed ‘Standards of Care’ (2009) and Physiotherapy Guidance paper ‘Physiotherapy Management of Screened Infants with CF’ (2008) (Appendix I) to complete a comprehensive support document for physiotherapists working in cystic fibrosis (CF). It covers infants, children and adults with Cystic Fibrosis.

All contributors are Chartered Physiotherapists and members of the Association of Chartered Physiotherapists in Cystic Fibrosis (ACPCF). This document has been developed independently of any funding bodies.

I.2 How to use this document

‘Standards of Care and Good Clinical Practice for the Physiotherapy Management of Cystic Fibrosis’ aims to be a useful tool and comprehensive reference document for all physiotherapists and others involved in the delivery of care to people diagnosed with cystic fibrosis from birth and throughout life. They incorporate the ‘Standards of Care’ document (2009), Physiotherapy Guidance paper ‘Physiotherapy Management of Screened Infants with CF’ (2008) (Appendix I), and also an update of the previously titled ‘Clinical Guidelines for the Physiotherapy Management of CF’ (2002), which highlights areas of ‘good clinical practice’ as well as summarising evidence-based recommendations. The endorsement process of the document by the CF Trust has included review by relevant experts as well as peer review.

The recommendations are intended to encourage physiotherapists to develop local guidelines tailored to their specific needs and circumstances. Good clinical practice points highlight areas of expert practice which are relevant to clinicians, but which also do not currently have substantive evidence.

I.3 Review of the document

This document will be reviewed in 2015 by the ACPCF and updated according to any new evidence available and/or changes in practice.

I.4 Grading scheme for recommendations in the document

In this document (with the exception of Appendix I ‘Physiotherapy Management of Screened Infants with CF’) the evidence used to support the recommendations has been graded using the Grading of Recommendations Assessment, Development and Evaluation* (GRADE) system. This was chosen over the previous grading scheme used in the original ‘Clinical Guidelines for the Physiotherapy management of CF’ (2002) of the ‘Scottish Intercollegiate Guidelines Network’** (SIGN) (this is still used in the aforementioned Appendix I, as this document was produced in 2009).

GRADE gives the clinician a useful tool in making clear, pragmatic interpretations of ‘Strong’ versus ‘Weak’ recommendations. As few areas of physiotherapy management in CF have sufficient and robust evidence, it is of paramount importance to inform the clinician about the quality of the evidence (QoE) (high, moderate, low or very low), which outcomes are critical, and the overall strength of the recommendation (Strong or Weak) to better inform their clinical reasoning and decision process. Although recommendations overall may be graded as ‘Strong’ (i.e. the degree of confidence that the desirable effects outweigh the undesirable) the quality of the evidence may be

moderate or low, due to the methodological issues within the studies available. Where there is no evidence to either support or refute practice, no recommendation is made.

*Kavanagh BP (2009) The GRADE System for Rating Clinical Guidelines. PLoS Med 6(9): e1000094. doi:10.1371/journal.pmed.1000094

**Petrie GJ, Barnwell E, Grimshaw J, on and behalf of the Scottish Intercollegiate Guidelines Network. *Clinical guidelines criteria for appraisal for national use*. Edinburgh, Royal College of Physicians, 1995.

2. PHYSIOTHERAPY NATIONAL STANDARDS OF CARE FOR PEOPLE WITH CYSTIC FIBROSIS (2009)

These Physiotherapy Standards have been produced by the Association of Chartered Physiotherapists in Cystic Fibrosis (ACPCF) in consultation with the Cystic Fibrosis Trust. They provide an audit tool which can be used to evaluate services provided.

2.1 How to use standards

The standards should be used in conjunction with the following documents:

- Standards of Care & Good Clinical Practice for the Physiotherapy Management of Cystic Fibrosis (2011)
- Centre Care / Shared Care / Network Care: Care of Patients with Cystic Fibrosis in the UK (2008)
- CF Trust Standards of Care/Care pathway (www.cfcarepathway.org.uk)
- Clinical Guidance for the Physiotherapy Management of Screened Infants with Cystic Fibrosis (ACPCF Physiotherapy Guidance Paper 2008)
- Guidelines for the physiotherapy management of the adult, medical, spontaneously breathing patient. Section 3, Cystic Fibrosis (Joint BTS/ACPRC guideline 2009)
- Chartered Society of Physiotherapy Core Standards of Physiotherapy Practice (2005)
- Rules of Professional Conduct (2nd edition) (CSP Publication)
- *Pseudomonas aeruginosa* Infection in People with Cystic Fibrosis. Suggestions for Prevention and Infection Control. Second Edition. November 2004
- Methicillin-resistant *Staphylococcus aureus* (MRSA). April 2008
- The *Burkholderia cepacia* complex. Suggestions for Prevention and Infection Control. Second Edition. September 2004

2.2 Introduction

The majority of people with cystic fibrosis in the UK receive all or some of their care from a Specialist CF Centre. In some circumstances, particularly in the care of children, network care arrangements between a Specialist CF Centre and district general hospital have been developed. In 2008 the CF Trust convened a Consensus Group and produced a document entitled “Centre Care / Shared care / Network Care - Care of Patients with Cystic Fibrosis in the UK”. This document sets out a model of how CF care should be delivered to provide best care, whilst allowing for local variations.

It is recognised that physiotherapy services for people with CF are provided by physiotherapists with variations in the level of experience, knowledge and skill in the management of cystic fibrosis. These standards set out how physiotherapy services for CF patients should be provided. They cannot accommodate all variations and should be used as a framework for local application.

Physiotherapists working with CF patients fall broadly into three categories:

- **Group 1** “Specialist CF Physiotherapists” who have an in-depth knowledge and wide experience in the area of CF and respiratory care, e.g. working in a Regional CF Specialist Centre.

- **Group 2** Physiotherapists who work in the area of CF on a regular basis and are responsible for assessing, advising and treating people with CF as a significant part of their role e.g. working in a CF network clinic, lead physiotherapist on a ward where CF patients are regularly admitted for in-patient care.
- **Group 3** Qualified physiotherapists who have basic core skills who are involved in the management of people with CF as part of a wider remit e.g. rotational staff in the acute hospital setting (on the wards or in clinics), community staff who treat individuals with CF as part of a mixed caseload.

2.3 Definition of “Specialist CF Physiotherapist” *

- Working in a Centre with a minimum of 50 patients (adults or paediatrics)
- >50% of working time spent in CF
- Minimum of three years working with patients with CF
- Active member of CF special interest group e.g. ACPCF – includes attending meetings
- Attendance at a minimum of at least one multidisciplinary regional, national or international meeting annually
- CPD relevant to CF practice

*ACPCF and CF Trust definition November 2008

2.4 Physiotherapy standards

The standards are set out under the following headings:

1. Staffing
2. Service provision
3. Facilities
4. Equipment
5. Clinical standards
6. Infection control
7. Professional development and training

The document will be reviewed by the ACPCF and updated according to any new evidence available and/or changes in practice.

Standard 1: Staffing

People with cystic fibrosis should be cared for by physiotherapists with an appropriate level of expertise in the physiotherapy management of cystic fibrosis. There should be adequate staffing levels to maintain standards of care.

Criteria

1.1 The lead physiotherapist working in the Specialist CF Centre should be a Specialist CF Physiotherapist*.

1.2 All designated CF Network Clinics should have a named physiotherapist responsible for the care of people with CF (group 2). They will have strong links and regular two way communication with the CF Specialist Physiotherapist at the Specialist CF Centre.

1.3 All physiotherapists providing care for people with CF in settings other than the Specialist CF Centre should:

- Have access to specialist physiotherapy advice from the Specialist CF Centre.
- Have access to training/CPD in CF.
- Follow ‘Standards of Care & Good Clinical Practice for the Physiotherapy Management of Cystic Fibrosis’, ACPCF (2011).
- Follow local treatment guidelines as set out by the Specialist CF Centre.

1.4 Recommended physiotherapy staffing levels are set out in the “Standards for the Clinical Care of Children and Adults with Cystic Fibrosis in the UK ” (2001). However in May 2010 a working group revised these staffing levels and the table below shows these revised staffing levels.

The table shows suggested **Physiotherapist (W.T.E.)**

	75 patients	150 patients	250 patients
ADULT CENTRES (WTE)	2	4	6
P A E D I A T R I C CENTRES (WTE)	2	3	4

* See definition in introduction

Standard 2: Physiotherapy service provision

Individuals with CF should have an appropriate physiotherapy service from sufficiently skilled individuals at different stages of their care in different settings.

Criteria

2.1 Diagnosis

- All people newly diagnosed with CF (either through newborn screening or later diagnosis) should see a Specialist CF Physiotherapist soon after diagnosis.
- Care may be provided jointly by the Specialist and Network physiotherapists, but there should be a clear management plan and regular communication between all involved.
- For infants, “Recommendations for Practice” stated in the Clinical Guidance for the Physiotherapy Management of Screened Infants with Cystic Fibrosis (ACPCF Physiotherapy Guidance Paper 2008) should be followed.
- Frequency of input should be tailored to the individual but frequent assessment and advice will be required in the months following diagnosis. Access to physiotherapy should be weekly if required in the months following diagnosis.

2.2 Clinic

All individuals with CF should:

- Have access to a physiotherapist at each clinic visit. This will be a network centre physiotherapist, Specialist CF Physiotherapist or a joint consultation with both.
- See a Specialist CF Physiotherapist at least twice a year (one of these may be the annual review visit), and more frequently if required.
- Have the opportunity to visit a physiotherapist between clinic visits as required.
- Be reviewed as an out-patient during a course of intravenous antibiotics if community physiotherapy is not available.

2.3 Annual review

The physiotherapy annual review should be carried out by the Specialist CF Physiotherapist. If this is not possible, the physiotherapy annual review should be carried out under the supervision of, or be reviewed by, the Specialist CF Physiotherapist.

2.4 In-patients

- All individuals with CF admitted to hospital for in-patient care should have access to daily physiotherapy assessment and treatment as required.
- Patients admitted to hospital should be entitled to optimisation of physiotherapy and should receive a minimum of twice daily treatment, more frequently if required (unless an alternative regime is agreed by the patient/carer and the Specialist CF Physiotherapist).
- Individuals with CF or their carers should not be expected to provide their own daily in-patient physiotherapy because of shortfalls in physiotherapy staffing levels.
- If in-patient physiotherapy care is provided by non-specialist physiotherapists, advice from the Specialist CF Physiotherapist at the Specialist CF Centre should be sought and should be freely available.
- Individuals with CF admitted for in-patient care should have access to exercise facilities on a daily basis (weekdays as a minimum).
- Physiotherapy for daily airway clearance should be available at weekends as assessed by the usual weekday physiotherapist.
- Emergency on-call physiotherapy service should be available to CF in-patients overnight if required according to local policy.

2.5 Community/home care service

- Home care physiotherapy should be provided (if deemed appropriate) for people with CF at times of particular need e.g.:
 - At diagnosis
 - When changes in therapy delivery or technique are required
 - During chest exacerbation
 - In the event of palliative care at home
- When home IV treatment is prescribed, community physiotherapy at home or school should be available to support an optimisation in physiotherapy treatment. This should be once a week as a minimum or as deemed necessary by the Specialist CF Physiotherapist.

Standard 3: Facilities

People with CF should have access to appropriate facilities for their physiotherapy care as in-patients and out-patients.

Criteria

3.1 Facilities should recognise the need for privacy and dignity when carrying out airway clearance and exercise.

3.2 Adequate facilities for exercise should be available to people with CF as in-patients e.g. gym with adequate range of exercise equipment and sufficient space for aerobic exercise and exercise testing to be carried out.

3.3 Facilities for physiotherapy treatment must enable local infection control policies to be adhered to.

Standard 4: Equipment

All people with CF should be provided with appropriate respiratory and exercise equipment and will be trained in its use and maintenance.

Criteria

4.1 Patients should be provided with the respiratory equipment they require for use at home e.g. to nebulise medication, for airway clearance, for oxygen delivery and humidification.

4.2 There are written protocols for the use of the equipment used by and issued to patients.

4.3 All equipment is maintained, serviced, cleaned and sterilised according to the manufacturer's instructions and local policies.

4.4 Patients and families should be trained in the use of equipment supplied for home use.

4.5 Written instructions about the use, cleaning and sterilising procedures are issued to all patients taking equipment home.

4.6 There must be clear and adequate budget available for the provision of physiotherapy and nebulisation equipment, and clear responsibility as to who holds this budget.

Standard 5: Clinical standards

Physiotherapy clinical care should be based on best evidence available, and current ACPCF and CF Trust guidelines, protocols and consensus documents will be followed.

Criteria

5.1 Copies of all documents listed in the introduction should be available at Centres where people with CF receive care.

5.2 All physiotherapy staff caring for people with CF should be expected to read these documents during their induction period and areas for training and development identified.

5.3 There is evidence that the physiotherapy service provided for individuals with CF is regularly evaluated through clinical audit and quality assurance programmes.

Standard 6: Infection control

All physiotherapists working with people with CF should consider issues of hygiene and cross-infection.

Criteria

6.1 All staff should have knowledge of and work to: Local Infection Control Policies, CF Trust guidelines on prevention and infection control with *Burkholderia cepacia* complex, *Pseudomonas aeruginosa* and *MRSA* in people with CF.

6.2 All patients should have their own equipment: Compressors/nebulisers, O₂ equipment, airway clearance devices.

6.3 Physiotherapists should have access to records of individual microbiological status.

6.4 There should be rigid adherence to infection control policies when carrying out airway clearance, exercise, nebulisation and spirometry.

6.5 Staff should take all reasonable precautions to reduce the risk of cross-infection: rigorous hand-washing, pulse oximeters and exercise equipment decontaminated between patients, wearing of aprons and gloves for airway clearance therapy in accordance with local policy, stethoscopes decontaminated between patients, respiratory secretions handled with care (sputum pots to be covered and disposed of at least daily and soiled tissues disposed of immediately).

Standard 7: Professional development and training

Physiotherapists caring for people with CF have a professional responsibility to keep up to date with current CF research and continually to update their skills and knowledge to provide the best possible clinical care.

Criteria

7.1 Physiotherapists in groups 1, 2 and 3 should ensure they maintain their continual professional development (CPD) in general respiratory care and ensure they have adequate clinical skills to follow the Good Clinical Practice for the Physiotherapy Management of Children and Adults with CF (2010).

7.2 Physiotherapists in groups 1 and 2 should be members of the Association of Chartered Physiotherapists in Cystic Fibrosis (ACPCF) and attend local ACPCF meetings.

7.3 Physiotherapists in group 2 should attend annual local or regional CF study events (e.g. organised by Regional Specialist Centre).

7.4 Physiotherapists in group 1 should attend at least one CF meeting annually. This should be the annual national ACPCF study event or a national CF study days. They should have the opportunity to attend international CF conferences.

7.5 Physiotherapists in group 1 should demonstrate knowledge of current CF research and should be involved in CF research locally as appropriate.

3. OUTCOME MEASURES

Outcome measures are used for a variety of reasons including to assess the impact of the disease on daily function, assist in clinical decision making, assess the efficacy/effectiveness of treatment interventions within clinical practice and research, to assess the cost/benefit of a service and potentially to commission funding for a service. An outcome measure should be assessed for important clinimetric properties such as validity, reliability and responsiveness to treatment. In addition feasibility should also be assessed. Feasibility is multifaceted and refers to financial, practical and ethical considerations as well as patient and assessor acceptability.¹

The use of outcome measures relevant to physiotherapy is restricted by their complexity and feasibility (e.g. high resolution CT scan, radioisotope aerosol labelling). For the purpose of this document we have concentrated on outcome measures that could potentially be used to evaluate physiotherapy interventions.

Good practice point

- Factors influencing the choice of outcome measure include its purpose for use, clinimetric properties, and feasibility.

3.1 Airway clearance

There are currently few valid, reliable and responsive outcome measures for evaluating airway clearance interventions in cystic fibrosis. Many patients have normal chest x-rays, clinical scores, exercise tests and do not produce sputum, making assessment of change following an intervention difficult. Commonly used outcome measures in existing airway clearance trials include spirometry and sputum volume and weight.

With reference to spirometry it can be difficult to demonstrate a change in FEV₁ especially in patients with milder disease. Rate of decline in FEV₁ has been proposed as a useful alternative, although on an individual basis, spirometry is useful in monitoring a response to treatment (i.e. after a course of intravenous antibiotics) and provides clinicians with useful information. FEF₂₅₋₇₅ is also commonly used, however there are issues with variability of this outcome measure. More complex physiological assessments (e.g. lung clearance index) have been used to evaluate airway clearance interventions, however these often require specialist laboratory equipment and are not yet widely available.²⁻³

The use of sputum volume/weight as an outcome measure for research purposes/when looking at group outcomes is controversial, however, when evaluating treatment options in the individual it is often very helpful. If used, careful attention should be given to methodology (e.g. use of graduated sputum containers for measuring sputum volume and a calibrated scales for sputum weight) to ensure accuracy of results.

Other measures such as symptom scores, patient reported outcomes (e.g. CFQ-R quality of life questionnaire), cough frequency and exercise tolerance may also be appropriate outcome measures for airway clearance interventions. Several Cochrane reviews suggest that further work is required to identify appropriate outcome measures for airway clearance interventions.⁴⁻⁹ This work needs to focus on their clinimetric properties, and use across the disease trajectory (mild through to severe disease).

Good practice points

- Factors influencing the choice of outcome measure for airway clearance include its purpose for use, clinimetric properties, and feasibility.
- Respiratory physiotherapists should be using the best clinically applicable outcome measures to assess the efficacy of ACT on an individual basis. The outcome measures used may include:
 - Spirometry
 - Sputum volume, weight, colour, ease of expectoration
 - Cough frequency
 - Exercise tolerance
 - Patient reported outcomes e.g. CFQ-R, satisfaction, adherence, preference
 - Physiological assessments e.g. lung clearance index
 - Healthcare utilisation e.g. time to next exacerbation

3.2 Exercise testing

Clinical exercise testing is a valuable tool in assessing functional capacity and limitation, determining fitness levels, facilitating safe exercise prescription, providing a baseline for further testing and monitoring progress, and evaluating of an intervention. Exercise tests can also provide valuable information about a person's disease severity and guide oxygen prescription.^{10-11,14-15}

There are a range of exercise tests that can potentially be used as outcome measures in cystic fibrosis. Commonly used exercise tests include: cycle ergometry, treadmill tests, shuttle tests, walk tests and step tests.

Peak cycle ergometry is considered to be the gold standard for exercise testing in CF. It has been shown to be reliable, valid and responsive to change.¹²⁻¹⁴

Treadmill tests, using an incremental increase in speed and incline to exhaustion, are used widely within general respiratory disease and have been shown to be reliable and responsive to change.¹⁵⁻¹⁶ There has been little research using the treadmill test specifically in cystic fibrosis.

The shuttle walk test has been shown to be a reliable, valid and responsive measure of exercise capacity in chronic obstructive pulmonary disease (COPD).¹⁷⁻¹⁸ Within this protocol only walking is permitted; consequently patients with mild-moderate CF lung disease are often limited by being unable to walk fast enough and a maximal response is not achieved.¹⁹ The modified shuttle test added three new levels and allowed patients to run. It has been shown to be reliable, repeatable, valid and responsive to change in adults and children over seven years old with CF and varying severity of lung disease.¹⁹⁻²² This test is considered to require few resources and is relatively easy to carry out in the clinic environment.

Walk tests involve walking/running as fast as possible for a given amount of time; two, six and 12 minute tests have been investigated in patients with cystic fibrosis. The six-minute walk test is most thoroughly researched and there is data on validity, reliability and responsiveness in adults and children with CF.²³⁻²⁵ The main downfall of this test is that it is self-paced and therefore sub-maximal.

Step tests were developed to provide a relatively quick field test which can be carried out in the limited space of a hospital clinic. The three minute step test is externally paced and has been shown to be reliable and able to detect oxygen saturations²⁶⁻²⁷ however has shown mixed results in detecting

change compared to other exercise tests, especially in patients with mild to moderate lung disease. (see Appendix II).^{26,28}

While exercise tests focus on exercise capacity a variety of other outcome measures may be useful to measure actual participation in exercise and physical activity. These include exercise diaries, motion sensors and activities of daily living questionnaires all of which can elicit important information. Further work is required to assess their clinimetric properties, and use across the disease trajectory (mild through to severe disease) in CF, although they remain useful measures for clinicians to use in daily practice.

Good practice points

- The choice of exercise test should include careful consideration of its purpose for use, clinimetric properties, and feasibility.
- Patients with CF should have an exercise test annually.
- Consider cycle ergometry when selecting an exercise test.
- Consider modified shuttle test when selecting an exercise test if cycle ergometry is not available.
- Consider six-minute walk test when selecting an exercise test (and maximal testing is not available).
- Consider a treadmill test when selecting a maximal exercise test if cycle ergometry is not available.
- Consider three-minute step test when selecting an exercise test, particularly in those with more severe disease and if it is likely to provide the information required.

3.3 Other outcome measures

There are various methods for the subjective measurement of symptoms which can be used in conjunction with an exercise test, or in daily practice.

Borg Rating of perceived exertion scale has been shown to be a valid, and reliable score in measuring shortness of breath and perceived exhaustion in adults.²⁹⁻³⁰ The visual analogue scale (VAS) has also been shown to be a useful measure of shortness of breath and leg discomfort.³¹ Studies on validity and reliability have shown mixed results.

In children, it is very difficult to obtain a reliable score of subjective symptoms using measures designed for adults.³² Some objective measures of breathlessness in children have been studied and shown to have good correlation with objective outcomes of exercise, including the 15 count breathlessness score,³² breath hold time,³³ single breath counting score and sustained phonation time.³⁴ Some of these measures need further research to provide evidence of their validity, reliability and responsiveness in cystic fibrosis.

Good practice point

- Subjective measures of perceived exertion, breathlessness or fatigue should be used within an exercise test.

4. AIRWAY CLEARANCE

4.1 Active cycle of breathing techniques (ACBT)

The active cycle of breathing techniques consists of breathing control, thoracic expansion exercises, and the forced expiration technique. It can be adapted to individual need, but with each component of the cycle clearly defined. As it is not dependent on a device, it is one of the two airway clearance techniques, along with autogenic drainage, that every patient should be taught.

ACBT has been shown to be effective and efficient in the mobilisation and clearance of secretions³⁵⁻³⁶ and improvement in lung function.³⁷ It does not increase hypoxaemia³⁸ or airflow obstruction.^{35,39} It is not further improved by the addition of adjuncts such as positive expiratory pressure (PEP)⁴⁰ or Flutter®^{39,41} or high frequency chest wall oscillation.⁴² ACBT has been used in many short-term comparative crossover studies and when other techniques (e.g. oscillating PEP) include the forced expiration technique it has shown equivalence in amount of sputum cleared.⁴¹ Over a study period of one year, the ACBT is as equivalent in airway clearance effectiveness as autogenic drainage, PEP, or oscillating PEP.⁴³

Good practice points

- The length of each phase is flexible and should be adapted to individual patient need.
- ACBT is a useful technique in all stages of disease.
- All patients should be taught ACBT or autogenic drainage (AD) as neither is dependent on a device, and there are no contra-indications for use.
- Individual patient preference should be considered when formulating an airway clearance programme.

Recommendations

Strong

- *The ACBT should be considered when recommending an airway clearance technique for all patients with cystic fibrosis (as long as they are able to follow instruction) (QoE – low).*

4.2 Autogenic drainage (AD)

Autogenic drainage is a three-phased breathing regime using high expiratory flow rates at varying lung volumes to facilitate mucus clearance.⁴⁴⁻⁴⁶ The technique aims to maximise expiratory flow velocity to produce shearing forces and mobilise secretions. While expiratory flow should be high, it should not be forced and airway closure avoided. AD can be performed in any position.

Most of the studies of AD compare its efficacy with other airway clearance.^{43,47-53} However, all these studies have methodological problems, for example, small sample size or are of short treatment duration. A one-year study with five treatment arms (ACBT, AD, PEP, Flutter®, and Cornet) found no difference in efficacy for all techniques.⁴³ A long term trial of AD vs postural drainage (PD) showed no significant differences in pulmonary function between the two techniques and suggested that AD was at least as effective an airway clearance technique as PD.⁴⁸ Modified AD was reported to increase sputum weight when compared to PEP in a short-term study.⁵³ Other short-term comparative studies of AD with Flutter®⁵²⁻⁵³, postural drainage with percussion^{49,51} and high-PEP⁴⁹ have shown that AD was less effective at clearing sputum than the other techniques studied. A study

comparing AD with ACBT found that equal volume of sputum was cleared with both techniques, but that AD cleared sputum faster.⁴⁷ When changes in sputum rheology were compared between the Flutter® and AD, AD was found to be less effective at reducing sputum viscoelasticity.⁵³ Two short-term studies suggested that patients performing AD had led to fewer episodes of oxygen desaturation.⁴⁹ Studies that have looked at the effect of AD on lung function have shown a greater short-term increase in forced vital capacity (FVC) compared to high-PEP,⁴⁹ equal increase in FVC to Flutter⁵³ and no difference in values when compared to PD and percussion.^{48,52} It has been suggested that AD may be a preferable technique for patients with airway hyper-reactivity.⁴⁹ AD can also be used in children (assisted AD)⁵⁴⁻⁵⁶ where gentle manual pressure is applied on inspiration to guide the breathing level. No pressure is applied on expiration. Assisted AD is often combined with therapeutic exercise such as bouncing on an exercise ball.⁵⁵

Good practice points

- The avoidance of airway closure as described in AD may be beneficial particularly in patients with significant hyper-reactivity or unstable airways.
- In some circumstances it may be appropriate to combine AD with inhalation (for mucoactives) and/or other airway clearance devices e.g. IPV.
- Individual patient preference should be considered when formulating an airway clearance programme.

Recommendations

Strong

- *Consider autogenic drainage when choosing an airway clearance technique. There is some evidence to suggest that autogenic drainage is as effective as other airway clearance techniques (QoE – low).*

Weak

- *Consider autogenic drainage particularly in those with airway hyper-reactivity (QoE – very low).*
- *Consider autogenic drainage when choosing an airway clearance technique for a patient with cystic fibrosis who has shown decreases in oxygen saturations with other airway clearance techniques (QoE – very low).*

4.3 Positive expiratory pressure (PEP)

Applying a resistance during expiration provides a positive expiratory pressure which can be utilised to enhance the mobilisation of bronchopulmonary secretions. Periods of PEP breathing are combined with the forced expiration technique to facilitate airway clearance.

PEP breathing induces a temporary increase in functional residual capacity (FRC), increasing interdependence between alveoli, facilitating collateral ventilatory flow and therefore recruiting previously closed airways. It is suggested that the PEP induced increase in gas volume and pressure behind airway secretions make expiratory manoeuvres more effective.⁵⁷⁻⁵⁸

PEP may be applied via a mouthpiece or mask. Treatment is usually undertaken in the sitting position but may also be performed in positions to a particular area to increase ventilation e.g. supine or side

lying. Breathing through the device should be at tidal volume with only slightly active expiration (not prolonged or forced). In order to select the appropriate level of expiratory resistance a manometer should be inserted between the expiratory valve and the resistor to measure mid-expiratory pressure. The appropriate resistance is one which achieves a stable mid-expiratory pressure of 10-20cm H₂O.⁵⁹

Several studies have compared PEP with other methods of airway clearance both in the short^{40,59-74} and long-term (>1 year).⁷⁵⁻⁷⁹ A systematic review of PEP⁶ in CF reported that in single treatment or short-term studies no significant difference had been demonstrated between PEP and other airway clearance modalities in terms of forced expiratory volume in one second (FEV₁). The few longer term studies comparing PEP with other airway clearance techniques showed equivocal or conflicting results.⁶ Participant preference to PEP has been reported in several studies^{59,63-64,66,69,74,76,78-79} although the quality of many of these studies is reported as low.⁶ The use of PEP has also been investigated in infants and is reported to be as effective as postural drainage and percussion.⁷⁷

Good practice points

- No single treatment technique is suitable for all patients and the therapist delivering airway clearance should be well-educated in all aspects of airway clearance and associated therapy techniques.
- PEP has not been proven to be more or less effective overall than other airway clearance techniques.
- Patient preference should be considered when choosing an appropriate airway clearance modality.
- The level of the expiratory resistor used should be regularly re-assessed and may need to be changed with changes in clinical status.
- Individual patient preference should be considered when formulating an airway clearance programme.
- Patients must be instructed in appropriate cleaning regimens of PEP devices as per manufacturer guidelines.

Recommendations

Strong

- *PEP should be considered when recommending an airway clearance techniques for all patients with cystic fibrosis (QoE – low).*

4.4 Oscillatory devices in cystic fibrosis

Oscillatory devices are designed to alter the expiratory airflow. These devices are either intra- or extra-thoracic. Intra-thoracic oscillatory devices are placed in the mouth and provide resistance during exhalation which results in the airways vibrating thus loosening the mucus. Extra-thoracic oscillatory devices, such as an inflatable vest attached to a machine, vibrate at variable frequencies and intensities as set by the operator to ensure the individual's comfort and associated concordance.⁸

Oscillations or interruptions during expiratory airflow have been postulated to mechanically reduce the viscoelasticity of sputum and enhance mucociliary clearance.⁷⁹ Oscillations, both internally and externally, have also been considered to improve airway patency by preventing spontaneous compression through the introduction of alternating positive pressure where the consequent

vibration loosens mucus allowing ease of expectoration.^{39,80}

Intra-thoracic oscillations are generated orally and created using variable resistances within the airways generating controlled oscillating positive pressure which mobilises respiratory secretions. When the oscillation frequency approximates the resonance frequency of the pulmonary system, endobronchial pressure oscillations are amplified and result in vibrations of the airways. These vibrations loosen mucus from the airway walls. The intermittent increases in endobronchial pressure reduce the collapsibility of the airways during exhalation, increasing the likelihood of clearing mucus from the tracheobronchial tract. The airflow accelerations increase the velocity of the air being exhaled, facilitating the movement of mucus up the airways.⁸¹ Exhalation through these devices generates both oscillations of positive pressure in the airways and repeated accelerations of expiratory airflow that have been shown to result in improved sputum clearance.⁸² The devices frequently employed for this purpose are:

a. Flutter®

A small plastic device containing a large ball bearing which repeatedly interrupts the outward flow of air.^{81, 83}

b. Acapella

A flow-operated oscillatory PEP device, which uses a counterweighted plug and magnet to generate the oscillatory resistance.⁸⁴

c. Cornet

A horn-shaped tube which houses a rubber inner tube. The degree of rotation of this inner tube reflects the resistance generated. As the individual exhales through the horn the inner tube unfurls generating a rhythmic bending and unbending of the inner tube within the horn throughout the expiration phase.⁸³

d. Extra-thoracic oscillations (HFCWO)

Extra-thoracic oscillations are generated by forces external to the respiratory system, for example high frequency chest wall oscillation (HFCWO).⁸⁵ External chest wall oscillations are applied using an inflatable vest attached to a machine which vibrates at a variable frequencies and intensities as set by the operator to ensure the individual's comfort and associated concordance.

Oscillatory devices can be effective in clearing secretions, but despite evidence showing improvement in sputum volume, there is no statistically significant evidence to suggest that the use of these devices is superior to other physiotherapy techniques when respiratory function is the primary outcome.

Many of the studies included quality of life scales and satisfaction questionnaires, however few incorporated measures of adherence. When there is no marker of superiority between airway clearance techniques it may be prudent to include patient preference, adherence to therapy and general satisfaction with treatment as potential outcome measures in further studies of these techniques.⁸ Individual patient preference should be considered when formulating an airway clearance programme. As a consequence of improved adherence to therapy improvements may be seen in other parameters such as exercise tolerance and respiratory function.

Recommendations

Strong

- *Consider oscillatory devices when recommending an appropriate ACT for a patient with CF (QoE – low).*

Good practice points

- Consider patient preference and their health beliefs when selecting an appropriate ACT for a patient with CF.
- Consider the age appropriateness of specific airway clearance devices when recommending them for use as an ACT.
- HFCWO should be considered where adherence with other ACTs is problematic.
- No single treatment technique is suitable for all patients and the therapist delivering airway clearance should be well-educated in all aspects of airway clearance and associated therapy techniques.
- Patients must be instructed in appropriate cleaning regimens of oscillatory PEP devices as per manufacturer guidelines.

4.5 Intrapulmonary percussive ventilation (IPV)

Intrapulmonary percussive ventilation uses a mechanical device that combines internal thoracic percussion and inspiratory pressure through rapid mini bursts of air superimposed on a spontaneous breathing pattern. Expiration against the percussive element of the device leads to the maintenance of positive pressure within the airways.⁸⁶ The proposed methods of action include; the maintenance of small airway patency and prevention of airway closure and atelectasis, enhanced movement of secretions and improved distribution of nebulised medications in some patients.

A number of studies have investigated the use of IPV in cystic fibrosis.⁸⁶⁻⁸⁹ A comparative study of IPV and conventional chest physiotherapy reported no differences between the techniques in terms of pulmonary function and expectorated sputum.^{87,90} A single intervention study⁸⁶ compared IPV with ‘conventional physiotherapy’ and the Flutter® in a randomised cross-over design concluding that IPV and the Flutter® were equivalent to chest physiotherapy in terms of sputum cleared or change in pulmonary function measures from baseline. Both studies included stable children and adults however the sample sizes were small and only the short-term effects of the interventions were studied. Similar findings have been found in stable CF patients in the outpatient setting.⁹¹

A short-term randomised cross-over study compared the efficiency of IPV with CPT and high frequency chest wall compression (HFCWC).⁸⁹ All three treatment regimens had similar short-term efficacy in terms of sputum clearance with no positive or negative preference for comfort or convenience. Only one longer term study⁸⁸ compared IPV to ‘conventional physiotherapy’ over a six-month period and found no significant difference in hospitalisations or use of oral and intravenous antibiotic use. All patients who used IPV for the duration of the study reported they would continue with the device if given the opportunity.

Good practice points

- Combine IPV with inhalation therapy (e.g. hypertonic saline).

- Consider IPV for use in patients with small airways disease, airway hyper-reactivity and those with thick tenacious secretions.
- Consider using IPV in combination with airway clearance techniques such as ACBT and AD.
- Consider IPV in advanced disease particularly if airway clearance is limited due to fatigue.

Recommendations

Weak

- *Consider intrapulmonary percussive ventilation when recommending an airway clearance technique for adults with mild to moderate cystic fibrosis (QoE – very low).*

4.6 Postural drainage (PD)

Postural drainage incorporates specific positions to utilise gravity in draining individual lobes/segments of the lungs.⁹² With the introduction of alternative airway clearance techniques, changes in CF sputum viscosity (and associated microbiology) and evidence of the provocation of gastro-oesophageal reflux disease (GORD) in individuals (particularly infants) with CF⁹³⁻⁹⁵ PD is less commonly advocated. Despite this PD may still be used particularly in the presence of a lung abscess or localised pathology.

As PD is passive and relies purely on gravity and alterations in regional ventilation to mobilise secretions it should not be used as an airway clearance technique alone. In clinical practice, PD is used in conjunction with techniques such as ACBT, AD and PEP. Cecins et al⁹⁶ showed that side lying (modified PD) was as effective as side lying with head down tilt (PD) in a cohort of CF and non-CF bronchiectasis patients. This study also demonstrated an increase in dyspnoea with head down positioning. Generally PD is now modified and excludes the head down tilt.

Good practice points

- If GORD has been identified, consider using modified PD avoiding a head down tilt.
- PD or modified PD should always be combined with an airway clearance technique.
- If gravity assisted positioning is not beneficial, consider a comfortable position to perform airway clearance techniques in, such as sitting or high side lying.

4.7 Intermittent positive pressure breathing (IPPB)

Intermittent positive pressure breathing provides intermittent positive pressure ventilation (on inspiration only) that augments tidal volume, and indirectly improves ventilation. There is no published evidence for the use of IPPB in cystic fibrosis. However, clinical experience suggests it is a useful adjunct where there is increased work of breathing/fatigue due to impaired secretion clearance, or atelectasis due to mucus plugging.

Since IPPB is a form of non-invasive ventilation (NIV) for short-term use, some of the recommendations that apply to NIV are relevant. In addition, nebulisation is also possible using IPPB which offers advantages in patients with suppurative lung disease.

Good practice points

- IPPB should be used with a nebulised solution e.g. sterile water, normal saline, bronchodilator, or hypertonic saline. (However, this approach should not replace the patient's regular inhalation therapy regimen, as drug deposition through IPPB has not been systematically measured).
- Consider IPPB if patients have difficulty clearing secretions with conventional airway clearance techniques (e.g. tenacious secretions, high work of breathing).
- Consider use of the forced expiration technique (FET) to clear secretions after using IPPB.
- An oscillating PEP device or positive end expiratory pressure (PEEP) valve may be added on to the expiratory port in the circuit.

5. EXERCISE

5.1 Introduction

The importance of exercise in maintaining a healthy lifestyle is well recognised in both health and disease. There is a growing body of evidence showing that patients with CF are not only affected by decreased cardiorespiratory fitness (i.e. aerobic) but also decreased muscle power, strength and endurance (i.e. anaerobic).⁹⁷ Furthermore poor posture and flexibility are common features in patients with Cystic Fibrosis.⁹⁸

The current guidelines for physical activity for healthy children and adults are applicable in CF and can be used as a basis for exercise advice in CF until respiratory disease progresses.⁹⁹ Regular assessment of fitness, monitoring, advice and education on type and frequency of activity should be initiated from diagnosis in order to ensure fitness levels are maintained. As disease becomes more severe patients may need to have individually tailored exercise programmes that are frequently re-evaluated.

5.2 Evidence for physical training

A Cochrane systematic review on physical training for CF (updated in August 2008) provides a summary of randomized controlled trials (n=7) examining the efficacy of physical training (for both cardiorespiratory and muscular fitness) versus no physical training.⁵ Despite a lack of consistency in outcomes, as well as the specific measurement instruments used, the studies in this review show improvements in cardiorespiratory fitness, strength and some components of lung function. There is some evidence that FEV₁ does not change with physical training.¹⁰⁰⁻¹⁰³ There are specific benefits from different types of physical training and therefore patients should perform a combination of types of exercise. There is some evidence that physical training does not result in any decreases in weight.¹⁰⁰⁻¹⁰² There is also some evidence relating to the benefits of both cardiorespiratory and muscular fitness training in older children, adolescents and adults with CF.¹⁰⁴⁻¹⁰⁵ Due to absence of reported studies there is no evidence of the benefits of physical training exclusively in infants and younger children with CF (see Appendix I). There is some evidence of the effectiveness of flexibility and posture exercise interventions.⁹⁸

Good practice points

- All patients should participate in regular physical activity.
- The specialist multidisciplinary team should be involved in the decision to instigate or progress physical training programmes in CF.
- Modification of exercise levels should be considered during periods of clinical instability (e.g. during an exacerbation or following surgery), hypoxia and arthropathy.

Recommendations

Strong

- *Exercise (and assessment of adherence) should be an integral part of the management of patients with CF (QoE – moderate).*
- *Physical training programmes should incorporate a range of types of exercise (e.g. aerobic and anaerobic exercise) (QoE – moderate).*

Weak

- *Physical training should aim to reach the minimum level of activity as per Physical Activity guidelines (QoE – low).*
- *Patients should be familiarised regarding the use of subjective measures of perceived exertion or breathlessness in order to gauge levels of physical exercise (i.e. moderate versus vigorous) (QoE – low).*
- *Formalised physical training programmes should be introduced to supplement unstructured activities to ensure patients achieve the recommended levels of exercise (QoE – low).*
- *Patients with CF who do not meet the current guidelines should be encouraged to increase their exercise levels incrementally and in ways that they enjoy (QoE – very low).*
- *Patients with CF who meet/exceed the current guidelines should be encouraged to maintain their current levels of exercise and vary the types of exercise (QoE – very low).*
- *Flexibility and posture exercises should be incorporated into physical training programmes in CF (QoE – very low).*

5.3 Risks associated with specific exercise

There is limited evidence on the incidence of injuries during strength training in children and adolescents however the CSMF/AAP guidelines¹⁰⁶ state that specific types of strength training (e.g. power lifting, body building and maximal lifts) should be avoided until physical and skeletal maturity.¹⁰⁶ Prolonged exercise may increase the risk of dehydration and hyponatraemia particularly in warm or hot conditions which can reduce exercise capacity and lead to increased mucous viscosity and increased risk of exacerbation.¹⁰⁷ In patients with CFRD prolonged exercise may increase the risk of hypoglycaemia. Exercise at high altitude (e.g. skiing) may increase the risk of desaturation and right heart failure.¹⁰⁸⁻¹⁰⁹ Diving may increase the risk of pneumothorax especially in patients with more severe disease.¹⁰⁸ Contact sports (e.g. ball sports or combat sports) should be avoided in patients with advanced liver disease, pneumothorax, in patients with advanced disease or fractures especially in patients with low bone density.¹¹⁰

As disease progresses patients may be at increased risk of exercise induced desaturation and may require assessment for supplementary oxygen.¹⁰⁸ The use of positive pressure during or prior to exercise may also be considered. No trials have been conducted examining the efficacy of these interventions during physical training in CF.

Recommendations

Weak

- *Patients should be made aware of any increased medical risks associated with specific exercise or sporting activities (QoE – low).*
- *Specific types of strength training (e.g. power lifting, body building and maximal lifts) should be avoided until physical and skeletal maturity (QoE – low).*
- *Specific guidance should be given on fluid replacement and dietary/insulin requirements when appropriate (QoE – low).*
- *Patients who exhibit desaturation should be assessed for supplementary oxygen during exercise (QoE – low).*

5.4 Exercise testing in CF

Exercise testing has been used to predict prognosis, evaluate therapeutic interventions, investigate early disease, understand the physiological responses to physical exercise/activity, prescribe exercise programmes.¹¹¹⁻¹¹³ A wide range of exercise tests are available and choice depends on the purpose of exercise testing (see Appendix II). The gold standard for exercise testing is full cardiopulmonary exercise testing with cardiac, ventilatory and metabolic assessment (measuring several parameters including VO_2max) however this is not always accessible in all Centres and arguably not necessary/appropriate for all purposes. Tests that elicit a peak response may be more useful in assessing and monitoring exercise capacity and prescribing exercise programmes. Submaximal tests may be useful in assessing functional capacity. The use of subjective measures of perceived exertion, breathlessness or fatigue can be used to assess symptoms during exercise tests.

Good practice points

- Emergency procedures should be in place during exercise testing.
- Patients should be assessed for clinical stability prior to exercise testing.
- Exercise testing should be an integral part of the management of patients with CF.
- Exercise testing is important to assess fitness, and allow safe and effective exercise recommendations and monitor changes in fitness over time.
- Exercise testing is recommended at least on an annual basis and additionally when it is appropriate to re-evaluate physical fitness (e.g. examining efficacy of intervention or modifying exercise prescription).
- 1-RM tests should not be used to assess strength in children and adolescents.
- Subjective measures of perceived exertion, breathlessness or fatigue should be used to assess symptoms during exercise tests.

6. MUSCULOSKELETAL ISSUES AND POSTURAL MANAGEMENT

The combination of CF-related bone disease and abnormal respiratory mechanics lead to a higher than normal incidence of musculoskeletal pain, thoracic kyphosis and vertebral fracture rates in both adults and children with cystic fibrosis.¹¹⁴ Low bone mineral density is highly prevalent in adults with CF with 85% presenting with osteopenia and reports of 10%–34% presenting with osteoporosis.^{115–116} Contributing risk factors may include malnutrition, inflammation, vitamin D and K deficiency, altered sex hormone production, glucocorticoid therapy and physical inactivity. Childhood and puberty are critical times for bone mineralization, and it is suggested that strategies for optimising peak bone mass and offering preventative care are important from childhood.¹¹⁸

Progressive respiratory disease leads to altered ventilatory mechanics causing changes in chest wall structure (hyperinflation causing thoracic kyphosis and rib elevation). The forces generated due to the increased work of breathing and excessive coughing exert repetitive abnormal demands on a sub-optimal musculoskeletal system and lead to adverse postural changes such as thoracic kyphosis, spinal vertebral fractures, and joint pain.¹¹⁸

These structural changes affect the soft tissue structures of the chest wall and people with CF have been reported to have reduced shoulder and trunkal muscle strength and mobility.¹¹⁹ Trunk muscles are inextricably linked to both respiration and posture and will be compromised in order to focus on immediate respiratory needs.¹²⁰ Maintenance of optimal posture allowing muscles to function most efficiently, in order to maintain exercise capacity and secretion clearance, may become especially clinically important as patients' disease severity worsens.

There is an increasing body of evidence demonstrating the role of physiotherapy musculoskeletal techniques for the prevention and management of non-inflammatory pain and postural changes in both adults and children with cystic fibrosis.^{98,121–125} Three original research papers^{121–123}, a review paper with a case study⁹⁸ and two other review articles as expert opinion^{124–125} were identified.

An observational study quantifying postural changes in adults with CF reported that the angle of thoracic kyphosis was partly correctable by simple instruction in a group of adults with cystic fibrosis.¹²¹ Postural and functional improvement in case reports using a programme of chest mobility and strengthening exercises have been reported.⁹⁸ An interventional study¹²³ found reductions in the decline of FEV₁ and significant improvements in posture, chest wall mobility, body strength and subjective wellbeing in patients using similar techniques and postural correction and exercises over a 12-month period. Improvements have been reported from a single intervention study in both in- and out-patients presenting for treatment of musculoskeletal problems, that treatment with manual techniques and massage therapy could be effective in reducing pain and ease of breathing.

Good practice points

- Individual ergonomic advice should be given to all patients and should encompass advice for home, school, the workplace and for other activities.
- This should focus on good alignment and symmetry when undertaking any activity in sitting, lying and standing positions. And include positioning advice for physiotherapy treatments including during inhalation therapy, airway clearance and exercise.
- All patients should have at least an annual musculoskeletal and postural assessment from approximately age eight years (earlier if necessary).
- Assessment, monitoring and treatment of any musculoskeletal issues should be undertaken on a regular basis.

- All patients should be offered advice on the importance of good posture and posture re-education.
- Early referral to a musculoskeletal specialist is recommended when problems are reported or identified.

Recommendation

Weak

- *Musculoskeletal intervention and postural advice should be considered in all patients (QoE – very low).*

7. INHALATION THERAPY

7.1 Introduction

Inhalation therapy delivers a wide range of medications and various devices are available.¹²⁶ Physiotherapists are often involved with the choice of inhaled medications. Frequently the practicalities of inhaled therapy such as trials of medication, device selection, provision and education is undertaken by physiotherapists.¹²⁷

When using bronchodilators such as Salbutamol, Terbutaline Sulphate and Ipratropium Bromide, it is recommended that spirometry is used to assess the initial response to the medication¹²⁸ and regular re-assessment is carried out to ensure this is maintained.¹²⁹ Timing of post-dose spirometry is variable depending on the medication given. An increase of 15% in FEV₁ or FEF₂₅₋₇₅, 15 minutes following inhalation of a Beta 2 agonist and 30 minutes post anti-cholinergic agent, being suggested as significant.¹³⁰

Inhaled antibiotics, RhDNase and hypertonic saline may cause bronchoconstriction.¹³¹⁻¹³² A decrease of 10–15% FEV₁ or FEF₂₅₋₇₅ following inhalation defines significant bronchoconstriction.^{127,130,133} Should this occur a further test dose with pre-medication of a bronchodilator is advisable before commencement on any medication with a risk of bronchoconstriction.^{126-127,130,133-136} Premedication with a Beta 2 agonist is always used in those already taking a bronchodilator prior to inhalation of hypertonic saline and antibiotics.

7.2 Nebuliser devices

There are increasing numbers of nebuliser devices available. The most common types available are: conventional nebulisation systems, ultrasonic nebulisers, adaptive aerosol delivery devices (AAD) and/or vibrating mesh technology systems (VMT).

There is little evidence to recommend one type of nebuliser device over another in terms of randomised trials demonstrating improved clinical efficacy or patient preference. There is however an indication that new nebuliser technologies such as AAD and VMT have advantages over conventional systems. These include speed of nebuliser administration with AAD¹³⁷ and VMT devices being quieter. They may also provide better deposition¹³⁸ and more consistent dosing.¹³⁹ Further high quality trials are needed to confirm these suggestions.¹⁴⁰ Appropriate cleaning and maintenance of nebuliser equipment is essential to avoid bacterial contamination of the equipment, to decrease the risk of acquiring pathogens and to ensure efficiency of the delivery of inhaled medication.^{126,141-142}

7.3 Timing of medications

It is generally suggested that nebulised antibiotics should be taken after physiotherapy and after bronchodilators in order to ensure best deposition and protection from bronchoconstriction.¹³³ Questions remain around the optimal timing of RhDNase. Studies have suggested that inhalation either pre or post airway clearance is equally effective.¹⁴³⁻¹⁴⁴ Others suggest that inhalation 30 minutes pre airway clearance may improve small airway patency more than inhalation post airway clearance.¹⁴⁵ Hypertonic saline should be taken immediately prior to or during airway clearance as it is thought to have an immediate mode of action. This may be dictated by individual patient preference.

7.4 Adherence

Adherence should be assessed after a period of use of nebulised antibiotics.¹⁴⁶ Monitoring adherence

levels has become easier and more accurate with the advent of AAD technology which provides detailed monitoring including date, time, completeness of dose and time taken to nebulise. Evidence suggests adherence to nebulised medications can be low and/or variable¹⁴⁷⁻¹⁴⁹ and monitoring allows greatly improved accuracy in identifying adherence levels and is acceptable in the CF population.^{147, 149} Reducing treatment to an optimum time of less than ten minutes has been suggested.^{130,141}

Good practice points

- Appropriate education for the use of inhalation devices and treatment strategy should be given and ongoing support provided.
- Physiotherapists should remain aware of nebuliser developments in order to offer the most appropriate device.
- Regular reassessment of the response to bronchodilators should be carried out where appropriate.
- Cleaning and maintenance education should be an integral aspect of the provision of nebuliser equipment.
- When adherence to inhaled therapy is poor clinicians should aim to use the quickest and simplest device possible for each medication.
- A mouthpiece should be the preferred route of delivery for standard nebulisers.

Recommendations

Strong

- *A test dose should be performed in order to assess suitability and/or effectiveness of the medication for the individual (QoE – moderate).*
- *Consideration should be given to intelligent nebuliser technologies such as AAD and VMT (QoE – low).*

Weak

- *Relaxed tidal volume breathing through the mouth and not the nose is recommended for patients using nebulised antibiotics (QoE – very low).*
- *Expiratory filters should be used to avoid environmental contamination with exposure of others to the medication and also to avoid damage to property (QoE – very low).*

8. NON-INVASIVE VENTILATION

8.1 Introduction

Non-invasive ventilation (NIV) is ventilatory support provided via a mask or mouthpiece. It is accepted as a management tool for hypercapnic respiratory failure, nocturnal hypoventilation or as a bridge to lung transplantation.^{127,150-151} It may also be used as an adjunct to airway clearance and to facilitate exercise. Physiotherapists may be involved in the assessment, set-up of equipment and monitoring of NIV.^{127,150}

8.2 NIV for airway clearance

NIV may be useful as an adjunct to physiotherapy in patients with CF but there is a lack of robust evidence to support its use.¹⁵⁰ Three adult^{67, 152-153} and one paediatric¹⁵⁴ trials have been undertaken and demonstrate a reduction in fatigue following airway clearance including NIV compared to airway clearance without NIV. A positive effect was also demonstrated on respiratory rate,¹⁵³ respiratory muscle strength¹⁵² and oxygenation.^{67,152} A systematic review of the evidence did not show an increase in sputum clearance¹⁵¹ although two studies reported a patient preference for this technique.^{67,152}

8.3 NIV for exercise

Clinically NIV has been reported to be used during exercise to decrease dyspnoea, improve oxygenation and ultimately improve exercise tolerance. However there are no trials to support.

8.4 NIV for respiratory failure

Previous guidelines¹⁵⁰ reported little evidence for the use of NIV in cystic fibrosis. A retrospective study¹⁵⁵ showed that NIV used during respiratory failure improves hypoxia and suggested that NIV may prolong life in those awaiting lung transplantation who demonstrate respiratory failure. There are no trials in the paediatric CF population evaluating the use of NIV in children with respiratory failure.

8.5 NIV for nocturnal hypoventilation

Three adult trials assess the use of NIV for nocturnal ventilation.¹⁵⁶⁻¹⁵⁸ These show an improvement in gas exchange during sleep with a reduction in pCO₂. Improvements in exercise tolerance and dyspnoea are also reported¹⁵⁷⁻¹⁵⁸ to a greater extent than supplemental oxygen in isolation in those who have baseline hypercapnia. There are variable reports in patient tolerance and preference for oxygen therapy alone or with NIV.^{156,158} Further research is required.

Good practice points

- As NIV is often used in advanced disease, appropriate radiological investigations should have been undertaken prior to commencement of therapy to ensure the presence of an undrained pneumothorax or enlarged bullae have been excluded.
- Appropriate monitoring and review should be carried out during the use of NIV to ensure optimal therapy is applied.
- A selection of interfaces; mouthpieces, nasal pillows, nasal masks, full face masks and total face masks should be available and used appropriately according to individual assessment.
- NIV may be used to facilitate airway clearance, and for ventilatory support in both adults and children.

- NIV may be considered for use during exercise where dyspnoea or oxygenation limits activity despite optimal regimen and oxygen therapy. Use of NIV during exercise should be monitored carefully as little is known about the outcomes of this intervention.

Recommendations

Strong

- *NIV should be considered for all people with CF demonstrating nocturnal hypoventilation with a rise in $p\text{CO}_2$ (QoE – moderate).*

Weak

- *NIV should be considered if fatigue is limiting airway clearance (QoE – low).*
- *NIV should be considered as an adjunct where desaturation is present during airway clearance (QoE – very low).*
- *NIV should be considered where there is difficulty clearing secretions with other techniques (QoE – very low).*
- *NIV should be considered for those in ventilatory failure in terms of improved oxygenation (QoE – low).*

9. MANAGEMENT OF SPECIFIC ISSUES

9.1 Urinary incontinence in cystic fibrosis

Urinary incontinence (UI) is more common in the female CF population (women and young girls) than the healthy population.¹⁵⁹⁻¹⁶⁶ Onset of UI has been reported in girls as young as 9-11 years.¹⁶³⁻¹⁶⁴ Symptoms of UI in males with CF do occur, but to a lesser degree than in females.¹⁶⁶

The risk factors associated with UI in CF are multi-factorial and may include muscle imbalance, weak pelvic floor musculature, poor nutritional status and increased intra-abdominal pressure which may result from repeated persistent coughing or hepatomegaly. The primary causes of UI in the CF population are coughing and forced expiratory manoeuvres. Therefore individuals with CF and UI may experience difficulty performing airway clearance or lung function procedures. In those affected, leakage of urine also often occurs during activities such as sneezing and laughing, impacting on daily life. The occurrence of UI seems to increase at times when cough is worse such as during a chest exacerbation.¹⁶⁰ The amount of leakage reported varies greatly and can be from a few drops to emptying the full bladder.¹⁶⁰ The occurrence and severity of UI increases as disease progresses¹⁵⁹⁻¹⁶⁰ and has also been found to have a significant impact on many aspects of quality of life.¹⁶⁶ Despite its physical and social implications, UI is an under-reported problem in Cystic Fibrosis.

Three studies have addressed the assessment and treatment of the pelvic floor muscles.¹⁶⁸⁻¹⁷⁰ An improvement in pelvic muscle endurance was reported following a three-month programme of pelvic floor exercises in a small self-selected group of CF female adults.¹⁶⁸ A three-month intervention of pelvic floor muscle training, electrical stimulation, biofeedback and bladder training resulted in patients reporting significantly fewer episodes of leakage and an improvement in EMG and ultrasound imaging measures.¹⁶⁹ Tension-free vaginal taping has also been reported as a safe and effective solution for stress incontinence in a very small sample of women with cystic fibrosis.¹⁷⁰

Good practice points

Patients should be taught controlled and effective coughing during airway clearance.

- The ‘knack’ (a quick, voluntary contraction of pelvic muscles to help prevent urine leakage during a rise in intra-abdominal pressure) may be a useful technique to use before coughing or performing forced expiratory manoeuvres.
- A sensitive and open approach with early recognition of symptoms should be adopted.

Recommendations

Weak

- *Physiotherapists should include enquiry about presence of UI symptoms as a routine part of assessment from the age of 11 (QoE – high).*
- *Both preventative and active strategies for the management of UI should be adopted (QoE – low).*
- *Referral to a specialist physiotherapist should be considered in those with symptoms of UI (QoE – very low).*

9.2 Pregnancy

Pregnancy is well tolerated in women with cystic fibrosis with a good health status at baseline ($FEV_1 >60\%$ predicted) but associated with increased maternal and foetal complications in those with an $FEV_1 <60\%$ predicted.¹⁷¹ Normal outcomes for mother and baby should be possible in those with an ‘event-free’ pregnancy and birth. Many women however do experience difficulties in maintaining stability of their health during this time and pre-pregnancy risk factors for this include diabetes, inadequate nutrition and poor or declining lung function.

Due to the potential complications, wherever possible pregnancies should be carefully planned, with optimisation of health pre-conception and close monitoring during and after pregnancy in order to detect any decline in health status. Treatment for decline in lung function or nutrition should be proactive during and after pregnancy to ensure the best outcome for both mother and baby.¹⁷²

There are no prospective studies evaluating physiotherapy interventions during pregnancy. However, pregnancy has a significant impact on respiratory status and physiotherapy requirements are likely to change throughout the antenatal period.^{171,173-174}

If mothers have a pre-pregnancy FEV_1 of $>60\%$ and/or stability of their lung disease the outcome is likely to be better than for those with more advanced disease.¹⁷³ It has been suggested that patients with an $FEV_1 <60\%$ are more likely to need frequent changes in their ACT and may require the addition of positive pressure during hospital to admission to enhance ACT effectiveness and reduce work of breathing.¹⁷⁴

Good practice points

- Airway clearance techniques and inhalation therapy should be reviewed and modified as necessary during pregnancy.
- Several different techniques used alone or in combination may be introduced to maximise ventilation and utilise lung volumes that could be compromised by the growing baby.
- With a reduction in FRC as the pregnancy progresses airway closure into closing volumes may occur leading to a risk of hypoxia and impaired secretion clearance due to atelectasis. Proactive monitoring and escalation of treatment strategies with a low threshold for positive pressure (such as non-invasive ventilation or intermittent positive pressure breathing) may help to minimise these risks.
- If gastro-oesophageal reflux or nausea is problematic, physiotherapists should be aware of the impact of interventions on symptoms and modify treatment to limit symptoms. Time-efficient devices for inhalation therapy should be chosen where possible to reduce the time burden of treatment and prepare the patient for their routine once the baby is born.
- Attention should be paid to the clearance of the lung bases due to a reduction in functional residual capacity and early closing volumes, potentially causing trapping of secretions.
- The importance of pelvic floor exercises should be stressed, and the knack taught, to be used preceding any forced expiratory manoeuvres.
- Patients with low back pain or sacroiliac strain should be given postural advice and gentle exercise and, where appropriate, an abdominal support.
- Gastro-oesophageal reflux should be identified and treated if present.

Recommendations

Weak

- *Airway clearance techniques should continue throughout pregnancy and be modified as pregnancy progresses with consideration to the degree of breathlessness and discomfort (QoE – very low).*

9.3 Liver disease in cystic fibrosis

Cystic fibrosis associated liver disease (CFALD) affects up to 30% of people with CF and is the third most common cause of death. Almost all cases present in the first two decades of life with a peak incidence in adolescence.¹⁷⁵ There is a marked variation in presence and severity of disease and it is only a significant clinical problem in the minority. CFALD affects males females in a ratio of 2:1. It is the initial diagnostic finding in 1.5% of patients and there is a four-fold risk of developing CFALD in cases of meconium ileus.¹⁷⁶ No specific genotype/phenotype connection has been identified as being associated with CFALD.¹⁷⁷

Most cases of CFALD are detected on routine screening; cirrhosis with secondary portal hypertension is rare and only small proportion present with variceal bleeding, ascites or persistent jaundice.¹⁷⁸ Liver transplantation may be considered in end-stage liver disease. There is no data which examines the efficacy of physiotherapy interventions in patients with CFALD.

Good practice points

- Abdominal distension due to hepatosplenomegaly or ascites may restrict diaphragm excursion and cause basal atelectasis. In these circumstances supine positioning should be avoided; airway clearance techniques may be more comfortable and effective in an upright position.
- Contact sports should be avoided in those with hepatosplenomegaly.
- Physiotherapists should work closely with dietitians to optimise nutritional status to allow the patient to remain as active as possible and to exercise effectively.
- In the presence of abnormal clotting manual techniques should be avoided.
- Deficiency in regulatory mechanisms results in derangement in the extracellular fluid volume, and may lead to ascites, oedema or pleural effusion.¹⁷⁹ Careful attention to positioning for airway clearance and during exercise is important.
- In the presence of active variceal bleeding physiotherapy may need to be discontinued or carried out with extreme caution.
- Intensification of airway clearance (including treatment during anaesthesia) may be required if repeated anaesthetics are required for monitoring and management of oesophageal varices.
- Anaemia should be considered as a cause of breathlessness when carrying out respiratory assessment and anaemia may affect ability to exercise.
- In those with hepato-pulmonary syndrome monitoring of oxygen saturations SpO₂ during exercise and any physiotherapy interventions is important.

9.4 Haemoptysis in cystic fibrosis

Haemoptysis is the expectoration of blood from the airways and occurs in approximately 60% of patients with CF, with the median age of the first episode occurring between 18 and 30 years of age¹⁸⁰⁻¹⁸¹. Major haemoptysis occurs in approximately 1% of all patients with CF and is more frequent

as their disease progresses.¹⁸⁰⁻¹⁸¹ It is rarely seen in children younger than ten years.¹⁸⁰⁻¹⁸¹

The bleeding site usually arises from a bronchial artery, but many reports have also suggested aberrant origin of the haemorrhage from non-bronchial collateral vessels or from anastomoses between bronchial and non-bronchial circulation.¹⁸² The pathogenesis of haemoptysis has been attributed to the persistent inflammation of the airways and vascular growth which results in hypertrophied bronchial arteries.¹⁸³⁻¹⁸⁴ Chronic and acute inflammation weakens the vessel walls and often leads to episodic or persistent bleeding into the bronchial lumen.

Rigid bronchoscopy can be performed as a diagnostic measure in identification of the bleeding vessel, however there are some limitations to this and unless the vessel is bleeding at the time of bronchoscopy it is often difficult to localise. CT bronchial arteriogram is used to identify which vessels would benefit from bronchial arterial embolisation (BAE) and CT was shown to have a high sensitivity when compared to bronchoscopy for diagnosing bronchial arterial abnormalities.¹⁸⁵

The estimation of volume of blood expectorated is challenging and often can be under or overestimated.¹⁸⁶ Much of the literature considers the definitions of haemoptysis as follows:

Minor haemoptysis – streaking or <50ml in 24hr

Moderate haemoptysis <250ml in 24hr

Massive haemoptysis >250ml in 24hr

Mild haemoptysis or blood streaking within expectorated sputum is commonplace and often associated with pulmonary exacerbation. Generally this is self limiting and responds to a course of antibiotic therapy. Other medical treatment options suggested are; vitamin K, blood replacement and the use of tranexamic acid.^{181,187-188} In the event of a massive haemoptysis BAE is an accepted and effective method of controlling the bleeding.¹⁸²

Literature regarding the physiotherapeutic management of haemoptysis is lacking. There is no evidence to indicate that alteration in treatment strategies is necessary when mild haemoptysis has occurred. It has been suggested that enhanced airway clearance to aid the removal of purulent secretions contributing to the pulmonary exacerbation may be beneficial.¹⁸⁷ In the management of moderate and massive haemoptysis modification of physiotherapy is prudent. In theory positive pressure treatments may aggravate friable vessels and consideration should be given to discontinuing these in favour of more controlled breathing techniques such as ACBT or AD. Percussive devices and oscillatory devices should also be used with caution. There are fears that airway clearance therapies may dislodge a clot and exacerbate bleeding but this is unlikely, and if bleeding is related to the underlying infection and inflammation, clearance of airway secretions is an important component of care.¹⁸⁷ The use of hypertonic saline and RhDNase has been suggested to present a risk, although this remains unproven and Flume¹⁸⁷ found a decreased incidence of haemoptysis in patients who were using RhDNase.

Good practice points

Minor haemoptysis

- No immediate change to physiotherapy, reassure patient and continue with normal regime.

Moderate haemoptysis

- Caution with the use of positive pressure (internal, external or oscillatory).

- Consider airway clearance techniques such as ACBT or AD.
- Reduce vigorous exercise.
- Careful positioning (high side lying bleeding side down).
- Minimise vigorous or excessive coughing.
- There is no evidence to support the cessation of inhaled therapies which could potentiate coughing, but this should be assessed on an individual basis.

Massive haemoptysis

- Optimise oxygen and humidification.
- Following embolisation and in liaison with interventional radiologist resume normal airway clearance management.

9.5 Pneumothorax in cystic fibrosis

Spontaneous pneumothorax is defined as the presence of air in the pleural cavity, and is frequently considered a poor prognostic indicator, with the average survival rate of 24–30 months following the initial episode.¹⁸⁷⁻¹⁹⁰ A recent small paediatric study suggested this survival rate to be slightly better at 48 months.¹⁹¹

The annual incidence of spontaneous pneumothoraces in patients with CF is approximately 0.64% (1 in 167 patients),^{187-188,192-193} with the average age of incidence being 23 years of age.¹⁹⁴ Flume¹⁸⁷ found that 75% of patients experiencing a pneumothorax had an FEV₁ of <40% predicted. Specific pathogens and nebulised therapies have been linked to an increased risk of pneumothoraces however it is more likely that their presence reflects the severity of the airways disease and airflow limitation.^{194,195}

The primary goal for the medical management of pneumothoraces is to re-expand the lung and to prevent recurrence as recurrence rates in CF patients are high (20–75% of patients) and therefore more aggressive management is justified in this population.^{188,196-199} Medical management includes chest drain insertion, high flow oxygen therapy, and chemical or surgical pleurodesis. Surgical pleurodesis or pleural abrasion using video assisted thoracoscopic surgery (VATS) appears to be the most effective management option.¹⁸⁷⁻¹⁸⁸ Pleural procedures, including pleurodesis do not have a significant adverse effect on the outcome of later lung transplantation.¹⁹⁰

In addition it is suggested that supplemental oxygen at high flow rates generates a partial pressure gradient between the pleural cavity and end capillary blood by decreasing the partial pressure contribution of nitrogen, theoretically increasing the reabsorption of gas from the pleural cavity. Increased rates of reabsorption whilst on oxygen were demonstrated, in a small prospective study of ten patients, which extended into the paediatric age range.¹⁹¹

There is no literature outlining how CF patients with pneumothoraces should be managed from a physiotherapeutic perspective.

Good practice points

- Patients should be advised and taught how to avoid paroxysms of coughing.
- Ensure appropriate and adequate hydration to ensure mucus is readily expectorated.

- Ensure appropriate analgesia and enable the maintenance of thoracic expansion.
- Avoid the use of airway clearance techniques that increase positive pressure e.g. PEP, in favour of more controlled techniques such as ACBT, AD.
- Encourage gradual exercise and avoid upper limb resistance exercises in the first instance.
- Gradual re-introduction of therapy techniques using positive pressure when patient resumes manoeuvres such as respiratory function testing. This has been suggested at three months but there is no literature to support this.
- Diving should be avoided permanently following a pneumothorax.

9.6 Critical care

Admission to the critical care or intensive care unit is associated with a poor prognosis in cystic fibrosis. Factors associated with a poor outcome include prior colonisation with *Burkholderia cepacia* complex, rapid decline in FEV₁, and severe exacerbation.²⁰⁰ Positive outcomes are associated with potentially reversible conditions such as the acute management of haemoptysis or pneumothorax,²⁰¹ and post-operative management. Endotracheal intubation (mechanical ventilation) is associated with a poor prognosis.²⁰²⁻²⁰³ However, the outcome of treatment with non-invasive ventilation (NIV) is good²⁰³⁻²⁰⁴ and many Centres may manage NIV in high dependency or ward areas.

There are no published studies of physiotherapy management of the intubated and ventilated patient with cystic fibrosis.

Good practice points

- Ensure regular airway clearance is continued, and optimise humidification.
- Ensure good positioning for optimal ventilation and drainage of secretions.
- Commence rehabilitation as soon as practically possible.
- Consider extubation onto and weaning with non-invasive ventilation.
- Maintain close liaison between the critical care and CF multidisciplinary teams.

9.7 Physiotherapy intervention following bilateral lung transplant

The physiotherapy input following lung transplantation can be extremely varied and diverse and includes the management of the patient in the intensive care unit, on the ward and as an out-patient. Physiotherapy intervention includes treatments to improve functional capacity, muscle strength, joint range of movement and postural alignment. Other musculoskeletal issues may also need to be addressed along with appropriate short-term and long-term goal setting. Physiotherapy input may also involve respiratory weaning (weaning from a tracheostomy, NIV and oxygen support), liaison with gyms and pulmonary rehabilitation centres, organisation of nebuliser units and preparation for employment or for a major life goal.

There are no randomised control studies investigating the physiotherapy input and exercise training solely for patients with CF post-lung transplant. Studies investigating the effects of exercise/activity of daily living post-lung transplant have had mixed patient populations, including patients with COPD, emphysema, interstitial lung disease, pulmonary hypertension, alpha-1 antitrypsin deficiency.²⁰⁵⁻²⁰⁷ These studies included patients with both single and bilateral lung transplant.

A systematic review investigating the effects of exercise training in adults after lung transplantation²⁰⁸

found seven studies that fulfilled the inclusion criteria, two of which were randomised controlled trials, four prospective cohort studies and one controlled trial with healthy subjects. The majority of the studies investigated aerobic exercise training with two studies including resistance exercise and two studies investigating the effect of resistance exercise on lumbar bone mineral density. Exercise training showed positive effects on maximal and functional exercise capacity, skeletal muscle function and bone mineral density. Aerobic exercise training methods that produced positive effects included treadmill, cycle, arm ergometry and stairs. The variety of protocols and outcomes used in the studies included in the review made it impossible to provide specific exercise training recommendations following lung transplant.²⁰⁸

A study investigating exercise performance in patients with CF before and after bilateral lung transplant showed exercise capacity improved post-transplant but remained below the aged matched healthy controls.²⁰⁹ An increase was shown between peak exercise arterial-venous O₂ difference pre and post transplantation but was not of statistical significance. The investigators conclude that an impaired O₂ extraction was suggested to be the predominant mechanism limiting exercise capacity after transplantation and that this abnormality could not be solely explained by deconditioning or anaemia.

Good practice points

- Non-invasive ventilation may be needed postextubation particularly in those who have used it as a bridge to transplant.
- Liaison with the pain management team may be necessary to ensure effective airway clearance and participation in an exercise regimen.
- Due to vagal nerve denervation and impaired cough reflex post-transplant, appropriate airway clearance techniques should be used.
- The use of any positive/negative pressure adjuncts should be discussed with the surgeons before use due to the effect on the bronchial anastomosis.
- An individually tailored exercise programme including cardiovascular and resistance work to improve functional capacity should be introduced in line with the patient's goals. Resistance exercise is important to help combat the effects of the long-term steroids required with the immunosuppression regimen.
- High dose steroid therapy following a rejection episode can increase the risk of tendonitis, tendon rupture and osteoporotic changes. Care must be taken when advising on exercise programmes.
- Liaison with the dietitian to ensure that the exercise programme prescribed does not exceed calorific intake.

9.8 End-stage disease management and end of life care

Determining when an individual with CF has 'end-stage' disease is difficult. Factors such as increasingly frequent infective exacerbations associated with a rapid rate of decline in lung function, and respiratory failure are important considerations. Achieving stability with optimal medical management becomes more difficult and transitory, with a significant impact on quality of life. Individuals may experience 'end-stage' disease for many months, or decline may be comparatively rapid.

There are few studies examining end-stage disease management and end of life care in cystic fibrosis. In the short-term prognosis can often be uncertain, with an unpredictable response to antibiotics and respiratory failure²¹⁰ although the long-term outcome may be clearer. Despite vast clinical experience,

it is often difficult to predict if and when an acute exacerbation will be an individual's final one.²¹¹

Physiotherapists have a key role in end-stage disease management where much of the patient care is orientated to the alleviation of symptoms. As end-stage disease progresses, physiotherapy may need to be adapted to consider many different factors, and while it is important to appreciate the benefit it may give, it is also important to appreciate the possible burden it imposes.²¹²

Physiotherapists focus on maximising functional ability and comfort in order to enhance quality of life, and this does not change during end-stage disease management and end of life care.²¹³ Many of the symptoms experienced in end-stage disease (e.g. dyspnoea, anxiety, fear, secretions, and pain) can be alleviated with a variety of physiotherapy treatment options in conjunction with multidisciplinary and medication strategies.

Treatments may need to be combined for optimisation, be performed on non-invasive ventilation, be of short duration, or timed with symptom-relieving medications.

Few studies have directly addressed the input of physiotherapy during end of life care. In a retrospective analysis²¹³ common treatments included airway clearance with ACBT, IPPB, NIV, exercise, anxiety management and relaxation techniques, with a reduction in the use of airway clearance adjuncts such as PEP and oscillating PEP. Many individuals continued with airway clearance techniques to within 24 hours of death.

Good practice points

- Consider positive pressure such as IPPB or NIV to reduce work of breathing and provide symptomatic relief.
- Consider alternative techniques – positioning, breathing exercises, massage, and relaxation.
- Frequent, short treatment sessions may be required to maximise symptomatic relief but minimise fatigue.
- Physiotherapists are key members of multidisciplinary teams regarding end of life discussions.
- Ensure palliative care teams are included in end-stage management as well as end of life care, particularly regarding symptom control.

10. REFERENCES

1. Greenhalgh J, Long AF, Brettle AJ, Grant MJ. Reviewing and selecting outcome measures for use in routine practice. *J Eval Clin Pract.* 1998 Nov; 4(4):339-50.
2. Main E et al. Evaluation of lung clearance index as an outcome measure for airway clearance intervention studies. *Journal of CF* 2004; abstract 334.
3. Prasad SA, Dhouieb EMO. Clinical Guidance for the Physiotherapy Management of Screened Infants with Cystic Fibrosis. ACPCF Physiotherapy Guidance Paper no. 4 2008.
4. Bradley J M et al. Evidence for physical therapies (airway clearance and physical training) in CF: An overview of five Cochrane systematic reviews. *Respiratory Medicine* 2006; 100:191-201.
5. Bradley JM, Moran F. Physical training for cystic fibrosis. *Cochrane Database of Systematic Reviews* 2008, Issue 1. Art. No.: CD002768. DOI: 10.1002/14651858.CD002768.pub2.
6. Elkins M, Jones A, van der Schans CP. Positive expiratory pressure physiotherapy for airway clearance in people with cystic fibrosis. *Cochrane Database of Systematic Reviews* 2006, Issue 2. Art. No.: CD003147. DOI: 10.1002/14651858.CD003147.pub3.
7. Main E, Prasad A, van der Schans CP. Conventional chest physiotherapy compared to other airway clearance techniques for cystic fibrosis. *Cochrane Database of Systematic Reviews* 2005, Issue 1. Art. No.: CD002011. DOI: 10.1002/14651858.CD002011.pub2.
8. Morrison L, Agnew J. Oscillating devices for airway clearance in people with cystic fibrosis. *Cochrane Database of Systematic Reviews* 2009, Issue 1. Art. No.: CD006842. DOI: 10.1002/14651858.CD006842.pub2.
9. van der Schans CP, Prasad A, Main E. Chest physiotherapy compared to no chest physiotherapy for cystic fibrosis. *Cochrane Database of Systematic Reviews* 2000, Issue 2. Art. No.: CD001401. DOI: 10.1002/14651858.CD001401.
10. Moorcroft AJ, Dodd ME, Morris J, Webb AK. Symptoms, lactate and exercise limitation at peak cycle ergometry in adults with Cystic Fibrosis. *European Respiratory Journal* 2005; 25:1050-56.
11. McKone EF, Barry SC, Fitzgerald MX, Gallagher CG. Reproducibility of Maximal Cycle Ergometer Testing in Patients with Cystic Fibrosis. 1999 *Chest.* 116(2):363-8
12. Nixon G M et al. Early airway infection, inflammation and lung function in CF. *Archives of Diseases of Childhood* 2002; 87:306-311.
13. Pianosi P, LeBlanc J, Almudevar A. Peak oxygen uptake and mortality in children with cystic fibrosis. *Thorax* 2005; 60:50-54.
14. Nixon PA, Orenstein DM, Kelsey SF. Habitual physical activity in children and adolescents with cystic fibrosis. *Med Sci Sports Exerc* 2001; 33:30-35.
15. Bruce RA, Cooper MN, Grey GO, Fisher LD, Peterson DR. Variations in responses to maximal exercise in health and cardiovascular disease. *Angiology* 1973; 24(11); 691-792
16. Wessel HU, Strasburger JF, Mitchell BM. New standards for the Bruce treadmill protocol in children and adolescent. *Pediatr Exerc Sci* 2001; 13:392–401.
17. Singh SJ, Morgan MDL, Scott S, Walters D, Hardman AE. Development of a shuttle walking test of disability in patients with chronic airway obstruction. *Thorax* 1992; 47;1019-24.
18. Singh SJ, Morgan MDL, Hardman AE, Rowe C, Bardsley PA. Comparison of oxygen uptake during conventional treadmill test and the shuttle walk test in chronic airflow limitation. *European Respiratory Journal* 1994; 7:2016-20.

19. Bradley J, Howard J, Wallace E, Elborn S. Validity of a modified shuttle test in adult cystic fibrosis. *Thorax* 1999; 54:437-9.
20. Bradley J, Howard J, Wallace E, Elborn S. Reliability, Repeatability and Sensitivity of the Modified Shuttle Test in Adult Cystic Fibrosis. *Chest*. 2000 June; 117(6):1666-71.
21. Cox NS, Follett J, McKay KO. Modified shuttle test performance in hospitalised children and adolescents with cystic fibrosis. *Journal of Cystic Fibrosis* 2006; 5(3):165-70.
22. Coelho CC, da Silva Aquino E, Costa de Almeida D, Oliviera GC, de Castro Pnito R, Oliviera Rezende IM, Pasos C. Comparative analysis and reproducibility of the modified shuttle walk test in normal children and in children with cystic fibrosis. *Jornal Brasileiro de Pneumologia* 2007; 33(2):168-74.
23. Chetta A, Pisi G, Zanini A, Foresi A et al. Six-minute walking test in cystic fibrosis adults with mild to moderate lung disease: comparison to healthy subjects. *Respiratory Medicine* 2001 December; 95(12):986-991.
24. Cunha MT, Rozov T, Caitano de Oliviero R, Jardim JR. Six-Minute Walk Test in Children and Adolescents with Cystic Fibrosis. *Pediatric Pulmonology* 2006; 41:618-22.
25. Zeigler B, Rovedder PME, Lukrafka JL, Oliviero CL, Menna-Barreto SS, Dalcin PTR. Submaximal exercise capacity in adolescent and adult patients with cystic fibrosis. *Jornal Brasileiro de Pneumologia* 2007; 33(3):263-9.
26. Balfour-Lynn, IM, Prasad SA, Laverty A, Whitehead BF, Dinwiddie R. A Step in the Right Direction: Assessing Exercise Tolerance in Cystic Fibrosis. *Pediatric Pulmonology* 1998; 25:278-84.
27. Suri R, Metcalfe C, Wallis C, Bush A. Assessing the usefulness of outcomes measured in a cystic fibrosis treatment trial. *Respiratory Medicine* 2007; 101:254-69.
28. Narang I, Pike S, Rosenthal M, Balfour-Lynn IM, Bush A. Three-Minute Step Test to Assess Exercise Capacity in Children with Cystic Fibrosis With Mild Lung Disease. *Pediatric Pulmonology* 2003; 35:108-113.
29. Borg G, Dahlstrom H. The reliability and validity of a physical work test. *Acta Physiol Scan* 1962; Aug 55:353-61
30. Easton RG, Williams JG. Reliability of ratings of perceived effort regulation of exercise intensity. *British Journal of Sports Medicine* 1988; 22(4):153-5.
31. Cullen DL, Rodak B. Clinical utility of measures of breathlessness. *Respiratory Care*. 2002 Sep; 47(9):986-93.
32. Prasad SA, Randall SD, Balfour-Lynn IM. Fifteen-Count Breathlessness Score: An Objective Measure for Children. *Pediatric Pulmonology* 2000; 30:56-62.
33. Barnai M, Laki I, Gyurkovits K, Angyan L, Horvath G. Relationship between breath-hold time and physical performance in patients with Cystic Fibrosis. *European journal of Applied Physiology* 2005; 95:172-8.
34. Orenstein DM, Holt LS, Reconvict P, Campbell T, Nixon P. Measuring Ease of Breathing in Young Patients with Cystic Fibrosis. *Pediatric Pulmonology* 2002; 34:473-7.
35. Pryor JA, Webber BA, Hodson M et al. Evaluation of the forced expiration technique as an adjunct to postural drainage in the treatment of cystic fibrosis. *Br med J* 1979; 2:417-8.
36. Wilson GE, Baldwin AL, Walshaw MJ. A comparison of traditional chest physiotherapy with the active cycle of breathing in patients with chronic suppurative lung disease. *European Respir J* 1995; 8: (Suppl 19): 171S.

37. Webber BA, Hofmeyr JL, Morgan MDL, Hodson ME. Effects of postural drainage incorporating the forced expiration technique, on pulmonary function in cystic fibrosis. *Br J of Dis Chest* 1986; 80:353-9.
38. Pryor JA, Webber BA, Hodson ME. Effect of chest physiotherapy on oxygen saturation in patients with cystic fibrosis. *Thorax* 1990; 45:77.
39. Pryor JA, Webber BA, Hodson ME, Warner JO. The Flutter VRP1 as an adjunct to chest physiotherapy in cystic fibrosis. *Respir Med* 1994; 88:677-81.
40. Hofmeyr JL, Webber BA, Hodson ME. Evaluation of positive expiratory pressure as an adjunct to chest physiotherapy in the treatment of cystic fibrosis. *Thorax* 1986; 41:951-4.
41. Pike SE, Machin AC, Dix KJ, Pryor JA, Hodson ME. Comparison of Flutter VRP1 and forced expirations with active cycle of breathing techniques in subjects with cystic fibrosis. *Netherlands J of Med.* 1999; 54:S55-6.
42. Osman LP, Roughton M, Hodson ME, Pryor JA. Short-term comparative study of high frequency chest wall oscillation and European airway clearance techniques in patients with cystic fibrosis. *Thorax* 2010; 65:196-200.
43. Pryor JA, Tannenbaum E, Scott SF, Burgess J, Cramer D, Gyi K, Hodson ME. Beyond postural drainage and percussion: Airway clearance in people with cystic fibrosis. *J Cystic Fibrosis* 2010; 9:187-192.
44. Dab I, Alexander F. The mechanism of autogenic drainage studied with flow volume curves. *Monographs of Paediatrics* 1979; 10:50-53.
45. Schöni MH. Autogenic drainage: a modern approach to physiotherapy in cystic fibrosis. *Journal of the Royal Society of Medicine* 1989; 82 (Suppl.16):32-37.
46. David A. Autogenic Drainage - the German approach. In: Pryor JA. (ed) *Respiratory Care*. London, Churchill Livingstone 1991 pp. 65-78.
47. Miller S, Hall DO, Clayton CB, Nelson R. Chest physiotherapy in cystic fibrosis: a comparative study of autogenic drainage and the active cycle of breathing techniques with postural drainage. *Thorax* 1995; 50:165-169.
48. Davidson AG, Wong LT, Pirie GE, et al. Long-term comparative trial of conventional percussion and drainage physiotherapy versus autogenic drainage in CF. *Pediatric Pulmonology* 1992; 14:298.
49. Pflieger A, Theissl B, Oberwaldner B, Zach MS. Self-administered chest physiotherapy in cystic fibrosis: a comparative study of high-pressure PEP and autogenic drainage. *Lung* 1992; 170: 323-330.
50. McIlwaine PM, Davidson AG, Wong LT, et al. The effect of chest physiotherapy by postural drainage and autogenic drainage on oxygen saturation in cystic fibrosis. *Pediatric Pulmonology* 1991; 11:291.
51. Giles D R, Wagener J S, Accurso F J, Butler-Simon N. Short-Term Effects of Postural Drainage with Clapping vs Autogenic Drainage on Oxygen Saturation and Sputum Recovery in Patients With Cystic Fibrosis. *Chest* 1995; 108:952-954.
52. App EM, Kieselmann R, Reinhardt D, et al. Sputum rheology changes in cystic fibrosis lung disease following two different types of physiotherapy: Flutter vs autogenic drainage. *Chest* 1998; 114:171-7.
53. Lindemann H, Boldt A, Kieselmann R. Autogenic Drainage: efficacy of a simplified method. *Acta Univ Carol Med (Praha).* 1990; 36(1-4):210-2.
54. CF Trust Factsheet – Physiotherapy Treatment: Airway Clearance Techniques. Written by S.

Ammani Prasad, MCSP, Tamara Orska, MCSP, Kate Ferguson, MCSP, Penny Agent, MCSP and Mary Dodd, FCSP on behalf of the Association of Chartered Physiotherapists in Cystic Fibrosis. June 2007.

Found at: http://www.cftrust.org.uk/aboutcf/publications/factsheets/Airways-clearance-june07-for_web.pdf.

55. Van Ginderdeuren F, Malfroot A, Verdonck J et al. Influence of assisted autogenic drainage (AAD) and AAD combined with bouncing on gastro-oesophageal reflux (GOR) in infants under the age of 5 months. *J Cystic Fibrosis* 2003; 2 (suppl 1): A251
56. CF Trust Factsheet – Physiotherapy Treatment For Babies and Toddlers with Cystic Fibrosis. Written by S. Ammani Prasad, MCSP, Research Physiotherapist, Cystic Fibrosis Unit, Great Ormond Street Hospital for Children, London and reviewed by members of the Association of Chartered Physiotherapists in Cystic Fibrosis. May 2007. Found at: [http://www.cftrust.org.uk/aboutcf/publications/factsheets/FS_Physio_\(Babies__toddlers\)_-_web.pdf](http://www.cftrust.org.uk/aboutcf/publications/factsheets/FS_Physio_(Babies__toddlers)_-_web.pdf).
57. Andersen JB, Qvist J, Kann T. Recruiting collapsed lung through collateral channels with positive end-expiratory pressure. *Scand J Respir Dis* 1979; 60:260-266.
58. Groth S, Stavanger G, Dirksen H, Andersen JB, Falk M, Kelstrup M. Positive expiratory pressure (PEP-mask) physiotherapy improves ventilation and reduces volume of trapped gas in cystic fibrosis. *Clin Respir Physiol* 1985; 21:339-343
59. Falk M, Kelstrup M, Andersen JB, Falk P, Stovring S, Gothgen I. Improving the ketchup bottle method with positive expiratory pressure (PEP), in cystic fibrosis. *Eur J Resp Dis* 1984; 65:423-432.
60. Tonnesen P, Stovring S. Positive expiratory pressure (PEP) as lung physiotherapy in cystic fibrosis. *Eur J Respir Dis* 1984; 65:419-422.
61. Tyrrell JC, Hiller EJ, Martin J. Face mask physiotherapy in cystic fibrosis. *Archives of Disease in Childhood* 1986; 61:598-600.
62. van Asperen PP, Jackson L, Hennessy P, Brown J. Comparison of a positive expiratory pressure (PEP) mask with postural drainage in patients with cystic fibrosis. *Australian Journal of Paediatrics* 1987; 23:283-4.
63. Darbee J, Dadparvar S, Bensel K, Jehan A, Watkins M, Holsclaw D. Radionuclide assessment of the comparative effects of chest physical therapy and positive expiratory pressure mask in cystic fibrosis [abstract]. *Pediatric Pulmonology* 1990; Suppl 5:251.
64. McIlwaine PM, Davidson AGF. Comparison of positive expiratory pressure and autogenic drainage with conventional percussion and drainage therapy in the treatment of CF [abstract]. *Proceedings of the 17th European Cystic Fibrosis Conference* 1991; S8.4.
65. Mortensen J, Falk M, Groth S, Jensen C. The effects of postural drainage and positive expiratory pressure physiotherapy on tracheobronchial clearance in cystic fibrosis. *Chest* 1991; 100:1350-1357.
66. Steen HJ, Redmond AO, O'Neill D, Beattie F. Evaluation of the PEP mask in cystic fibrosis. *Acta Paediatrica Scandinavica* 1991; 80:51-56.
67. van der Schans CP, van der Mark TW, de Vries G, Piers DA, Beekhuis H, Dankert-Roelse JE, et al. Effect of positive expiratory pressure breathing in patients with cystic fibrosis. *Thorax* 1991; 46:252-256.
68. Lannefors L, Wollmer P. Mucus clearance with three chest physiotherapy regimes in cystic fibrosis: a comparison between postural drainage, PEP and physical exercise. *European Respiratory Journal* 1992; 5:748-753.

69. Braggion C, Cappelletti LM, Cornacchia M, Zanolla L, Mastella G. Short-term effects of three chest physiotherapy regimens in patients hospitalized for pulmonary exacerbations of cystic fibrosis: a cross-over study. *Pediatric Pulmonology* 1995; 19:16-22.
70. Kofler AM, Carlesi A, Cutrera R, Leone P, Lucidi V, Rosati S, et al. BiPAP versus PEP as chest physiotherapy in patients with cystic fibrosis [abstract]. *Pediatric Pulmonology* 1998; Suppl 17:344.
71. van Winden CM, Visser A, Hop W, Sterk PJ, Beckers S, de Jongste JC. Effects of flutter and PEP mask physiotherapy on symptoms and lung function in children with cystic fibrosis. *European Respiratory Journal* 1998; 12:143-147.
72. Padman R, Geouque DM, Engelhardt MT. Effects of the flutter device on pulmonary function studies among pediatric cystic fibrosis patients. *Delaware Medical Journal* 1999; 71(1):13-8.
73. Darbee JC, Ohtake PJ, Grant BJB, Cerny FJ. Physiologic Evidence for the Efficacy of Positive Expiratory Pressure as an Airway Clearance Technique in Patients with Cystic Fibrosis. *Physical Therapy* 2004; 84:524-537.
74. West K, M, Follett J. Acapella vs PEP mask therapy: a randomised trial in children with cystic fibrosis during respiratory exacerbation. *Physiotherapy Theory Practice* 2010; 26:143-9.
75. McIlwaine PM, Wong LT, Peacock D, Davidson AG. Long-term comparative trial of conventional postural drainage and percussion versus positive expiratory pressure physiotherapy in the treatment of cystic fibrosis. *Journal of Pediatrics* 1997; 131:570-574
76. Gaskin L, Corey M, Shin J, Reisman JJ, Thomas J, Tullis DE. long-term trial of conventional postural drainage and percussion vs positive expiratory pressure [abstract]. *Pediatric Pulmonology* 1998; Suppl 17:345
77. Costantini D, A, Brusa D, Delfino R, Fredella C, Russo, et al. PEP-mask versus postural drainage in CF infants a long-term comparative trial [abstract]. *Proceedings of the 24th European Cystic Fibrosis Conference*; 2001:100.
78. McIlwaine PM, Wong LT, Peacock D, Davidson AGF. Long-term comparative trial of positive expiratory pressure versus oscillating positive expiratory pressure (flutter) physiotherapy in the treatment of cystic fibrosis. *Journal of Pediatrics* 2001; 138:845-850.
79. Newbold ME, Tullis E, Corey M, Ross B, Brooks D. The Flutter Device versus the PEP Mask in the Treatment of Adults with Cystic Fibrosis. *Physiotherapy Canada* 2005; 57:199-207.
80. Oermann CM, Sockrider MM, Giles D, Sontag MK, Accurso FJ, Castile RG. Comparison of high-frequency chest wall oscillation and oscillating positive expiratory pressure in the home management of cystic fibrosis: a pilot study. *Pediatric Pulmonology* 2001; 32(5):372-7.
81. Konstan MW, Stern RC, Doershuk CF. Efficacy of the Flutter device for airway mucus clearance in patients with cystic fibrosis. *Journal of Pediatrics* 1994; 124(5 (Pt 1)):689-93.
82. Rogers D, Doull IJM. Physiological principles of airway clearance techniques used in the physiotherapy management of cystic fibrosis. *Current Paediatrics* 2005; 15(3):233-8.
83. Pryor J. Physiotherapy for airway clearance in adults. *European Respiratory Journal* 1999; 14(6):1418-24.
84. Volsko TA, DiFiore JM, Chatburn RL. Performance comparison of two oscillatory positive pressure devices: Acapella versus Flutter. *Respiratory Care* 2003; 48(2):124-30.
85. Warwick WJ, Hansen LG. The long-term effect of high frequency chest compression therapy on pulmonary complications of cystic fibrosis. *Pediatric Pulmonology* 1991; 11(3):265-71.
86. Newhouse PA, White F, Marks JH and Homnick DN. The intrapulmonary percussive ventilator and flutter device compared to standard chest physiotherapy in patients with cystic fibrosis.

Clinical Pediatrics 1998; 37, 7, 427-432.

87. Natale JE, Pfeifle J, Homnick DN. Comparison of intrapulmonary percussive ventilation and chest physiotherapy. A pilot study in patients with cystic fibrosis. *Chest* 1994; 105(6):1789-1793.
88. Homnick DN, White F, De Castro C. Comparison of effects of an intrapulmonary percussive ventilator to standard aerosol and chest physiotherapy in treatment of cystic fibrosis. *Pediatric Pulmonology* 1995; 20:50-55.
89. Varekojis SM, Herbert D, Flucke RL, Filbrun DA, Tice JS, McCoy KS and Castile RG. A comparison of the therapeutic effectiveness of and preference for postural drainage and percussion, intrapulmonary percussive ventilation and high-frequency chest wall compression in hospitalised cystic fibrosis patients. *Respiratory Care* 2003; 48(1):24-28.
90. McInturff SL, Shaw LI, Hodgkin JE, Rumble L, Bird FM. Intrapulmonary percussive ventilation (IPV) in the treatment of COPD (abstract). *Respiratory Care* 1985; 30(10):885.
91. Marks JH, Hare KL, Saunders RA, Homnick DN. Pulmonary function and sputum production in patients with cystic fibrosis: a pilot study comparing the PercussiveTech HD device and standard chest physiotherapy. *Chest* 2004; 125(4):1507-1511.
92. Lorin MI, Denning CR. Evaluation of postural drainage by measurement of sputum volume and consistency. *American Journal of Physical Medicine* 1971; 50: 215-9
93. Button BM, Heine RG, Catto-Smith AG, et al. Postural drainage in cystic fibrosis: is there a link with gastro-oesophageal reflux? *J Paediatr Child Health* 1998; 34:330-4.
94. Button BM, Heine RG, Catto-Smith AG, et al. Chest physiotherapy in infants with cystic fibrosis: to tip or not? A five-year study. *Pediatr Pulmonol* 2003; 35:208-13.
95. Button BM, Roberts S, Kotsimbos TC, et al. Gastroesophageal reflux (symptomatic and silent): a potentially significant problem in patients with cystic fibrosis before and after lung transplantation. *J Heart Lung Transplant* 2005; 24:1522-9.
96. Cecins NM, Jenkins SC, Pengelley J, Ryan G. The active cycle of breathing techniques – to tip or not to tip? *Respiratory Medicine* 1999; 93:660-5.
97. Selvadurai HC, Cooper PJ, Meyers N, et al. Validation of shuttle tests in children with cystic fibrosis. *Pediatric Pulmonology* 2003; 35:133-138.
98. Massery M. Musculoskeletal and neuromuscular interventions: a physical approach to cystic fibrosis. *J Royal Society Med* 2005; 98(suppl 45):55-66.
99. U.S. Department of Health and Human Services. Physical Activity Guidelines for Americans 2008. Available at: <http://www.health.gov/paguidelines/pdf/paguide.pdf>
100. Klijn PH, Oudshoorn A, van der Ent CK, van der Net J, Helders PJ. Effects of anaerobic training in children with cystic fibrosis: a randomised controlled study. *Chest* 2004; 125(4): 1299-305.
101. Selvadurai HC, Blimkie CJ, Meyers N, Mellis CM, Cooper PJ, Van Asperen PP. Randomized controlled study of in-hospital exercise training programs in children with cystic fibrosis. *Pediatric Pulmonology* 2002; 33(3):194-200.
102. Schneiderman-Walker J, Pollock SL, Corey M, Wilkes DD, Canny G, Pedder L, et al. A randomised controlled trial of a 3-year home exercise program in cystic fibrosis. *J Pediatr* 2000; 136(3):304-10.
103. Cerny FJ. Relative effects of bronchial drainage and exercise for in-hospital care of patients with cystic fibrosis. *Phys Ther* 1989; 69(8):633-9.
104. Orenstein DM, Hovell MF, Mulvihill M, Keating KK, Hofstetter CR, Kelsey S, et al. Strength

- vs aerobic training in children with cystic fibrosis: a randomised controlled trial. *Chest* 2004; 126(4):1204-14.
105. Gruber W, Orenstein DM, Braumann KM, et al. Health-related fitness and trainability in children with cystic fibrosis. *Pediatr Pulmonol* 2008; 43:953-964.
 106. Council on Sports Medicine and Fitness/American Academy of Pediatrics. Strength training by children and adolescents: Policy statement. *Pediatr* 2008; 121:835-840.
 107. Orenstein DM, Henke KG, and Green CG. Heat acclimation in cystic fibrosis. *J Appl Physiol* 1984; 57:408-412.
 108. Webb AK and Dodd ME. Exercise and sport in cystic fibrosis: benefits and risks. *Br J Sports Med* 1999; 33:77-78.
 109. Speechly-Dick ME, Rimmer SJ, Hodson M. Exacerbation of cystic fibrosis after holidays at high altitude: a cautionary tale. *Respir Med* 1992; 86:55-56.
 110. Haworth CS, Selby PL, Webb AK, and Adams JE. Osteoporosis in adults with cystic fibrosis. *J R Soc Med* 1998; 91 Suppl 34:14-18.
 111. Barker M, Hebestreit A, Gruber W, et al. Exercise testing and training in German CF centres. *Pediatr Pulmonol* 2004; 37:351-355.
 112. Rogers D, Prasad SA, Doull I. Exercise testing in children with cystic fibrosis. *J Royal Society Med* 2003; 96 (Suppl 43):23-29.
 113. Stevens D, Williams CA. Exercise testing and training with the young cystic fibrosis patient. *J Sports Sci Med* 2007; 6:286-291.
 114. Koch AK, Bromme S, Wollschlager B, Horneff G, Keyszer G. Musculoskeletal manifestations and rheumatic symptoms in patients with cystic fibrosis (CF) no observations of CF-specific arthropathy. *J Rheumatol* 2008 Sep; 35(9):1882-91.
 115. Elkin SL, Fairney A, Burnett S et al. Vertebral deformities and low bone mineral density in adults with cystic fibrosis: a cross-sectional study. *Osteoporosis Intl* 2001; 12:366-372.
 116. Haworth CS, Selby PL, Webb K et al. Low bone mineral density in adults with cystic fibrosis. *Thorax* 1999; 54:961-967.
 117. Sermet-Gaudelus I, Castanet M, Retsch-Bogart G, Aris RM. Update on cystic fibrosis-related bone disease: a special focus on children. *Paediatr Respir Rev* 2009 Sep; 10(3):134-42.
 118. Parasa RB, Maffulli N. Musculoskeletal involvement in cystic fibrosis. *Bull Hosp Jt Dis* 1999; 58(1):37-44.
 119. Rose J, Gamble J, Schultz A, Lewiston N. Back pain and spinal deformity in cystic fibrosis. *Am J Dis Child* 1987; 141(12):1313-6.
 120. Hodges PW, Gurfinkel VS, Brumagne S, Smith TC, Cordo PC. Coexistence of stability and mobility in postural control: evidence from postural compensation for respiration. *Exp Brain Res* 2002 Jun; 144(3):293-302.
 121. Tattersall R, Walshaw MJ. Posture and cystic fibrosis. *J R Soc Med* 2003; 96 Suppl 43:18-22.
 122. Lee A, Holdsworth M, Holland A, Button B. The immediate effect of musculoskeletal physiotherapy techniques and massage on pain and ease of breathing in adults with cystic fibrosis. *Journal of Cyst Fibrosis* 2009 Jan; 8(1):79-81.
 123. Demry A, Ben Ami S, Levi M, Eizenstadt I, Kerem E, Yahav J, et al. Chest strength and mobility training: a new approach to airways clearance. *Journal of Cystic Fibrosis* 2006; 29:371.
 124. Dodd ME, Prasad SA. Physiotherapy management of cystic fibrosis. *Chron Respir Dis*

2005;2(3):139-49.

125. Lannefors L, Button BM, McIlwaine M. Physiotherapy in infants and young children with cystic fibrosis: current practice and future developments. *J R Soc Med* 2004; 97 Suppl 44:8-25.
126. Heijermann H, Westerman E, Conway S, Touw D, Döring G. Inhaled medication and inhalation devices for lung disease in patients with cystic fibrosis: A European consensus. *Journal of Cystic Fibrosis* 2009; 8:295-315.
127. Bott J, Blumenthal S, Buxton M, Ellum S, Falconer C, Garrod R, Harvey A, Hughes T, Lincoln M, Mikelsons C, Potter C, Pryor J, Rimington L, Sinfield F, Thompson C, Vaughn P, White J. Physiotherapy management of the medical respiratory patient: the adult spontaneously breathing patient. *Thorax* 2009; 64(suppl1).
128. Halfhide C, Evans HJ, Couriel J. Inhaled bronchodilators for cystic fibrosis. *Cochrane Database of Systematic Reviews* 2005, Issue 4. Art. No.: CD003428. DOI: 10.1002/14651858.CD003428.pub2.
129. Holzer FJ, Olinsky A, Phelan PD. Variability of airways hyper-reactivity and allergy in cystic fibrosis. *Arch Dis Child* 1981 Jun; 56(6):455-459.
130. British Thoracic Society. BTS guidelines on current best practice for nebuliser treatment. *Thorax* 1997; 52(Suppl 2):S1e106.
131. Dodd ME, Abbott J, Maddison J, et al. Effect of tonicity of nebulised colistin on chest tightness and pulmonary function in adults with cystic fibrosis. *Thorax* 1997; 52:656.
132. Cunningham S, Prasad A, Collyer L, et al. Bronchoconstriction following nebulised colistin in cystic fibrosis. *Arch Dis Child* 2001; 84:432e3.
133. Webb AK, Dodd ME. Nebulised antibiotics for adults with cystic fibrosis. *Thorax* 1997; 52(suppl 2):S69-S71.
134. Pasteur MC, Bilton D, Hill AT. Guidelines for non CF Bronchiectasis. *Thorax* 2010; 65 (suppl 1).
135. Donaldson SH, Bennett WD, Zeman KL, Knowles MR, Tarran R, Boucher RC. Mucus clearance and lung function in cystic fibrosis with hypertonic saline. *N Engl J Med* 2006; 354:241-250.
136. Elkins MR, Robinson M, Rose BR, Harbour C, Moriarty CP, Marks GB, Belousova EG, Xuan W, Bye PT: National Hypertonic Saline in Cystic Fibrosis (NHSCF) Study Group. A controlled trial of long-term inhaled hypertonic saline in patients with cystic fibrosis. *N Engl J Med* 2006; 354:229-240.
137. Denyer J, Prince I, Dixon E, Agent P, Pryor J, Hodson M. *Journal of Aerosol Medicine and Pulmonary Drug Delivery*. April 2010, 23(s1): S-29-S-36. doi:10.1089/jamp.2009.0768.
138. Mullinger B, Sommerer K, Herpich C, Meyer G, Scheuch G. Inhalation therapy can be improved in CF patients by controlling the breathing pattern during inspiration. *J Cyst Fibros* 2004; 3:S65.
139. Potter R, Hatley RHM. Precise dose delivery of colistimethate sodium using prototype I-neb AAD system. *J Cyst Fibros* 2005; 4 (Suppl 1):S30.
140. Daniels T, Mills N, Whitaker P. Nebuliser devices for drug delivery in cystic fibrosis (Protocol). *Cochrane Database of Systematic Reviews* 2009; Issue 1. Art. No.: CD007639. DOI: 10.1002/14651858.CD007639.
141. Cystic Fibrosis Trust, 2002. Antibiotic treatment for cystic fibrosis. London: Cystic Fibrosis Trust.
142. Lannefors L, Heslop K, Teirlinck C. Nebuliser systems, contamination, microbial risks, cleaning

- and effect on function. *Eur Respir Rev* 2000; 10:571e5.
143. Fitzgerald DA, Hilton J, Jepson B, Smith L. A crossover, randomized, controlled trial of dornase alfa before versus after physiotherapy in cystic fibrosis. *Pediatrics*. 2005; 116(4):549-54.
 144. Wilson CJ, Robbins LJ, Murphy JM, Chang AB. Is a longer time interval between recombinant human deoxyribonuclease (dornase alpha) and chest physiotherapy better?: A multi-center, randomised crossover trial. *Pediatric Pulmonology* 2007; 42(12):1110-1116.
 145. van der Giessen LJ, de Jongste JC, Gosselink R, et al. RhDNase before airway clearance therapy improves airway patency in children with CF. *Pediatric Pulmonology* 2007; 42:624-30.
 146. Webb AK, Dodd M, Bush A. Nebulised antibiotics in cystic fibrosis and non-CF bronchiectasis in children and adults. In: Boe J, O'Driscoll R, Dennis J, eds. *Practical handbook of nebuliser therapy*. London: Martin Dunitz, 2004.
 147. McNamara P, McCormack P, McDonald AJ et al. Open adherence monitoring using routine data download from an adaptive aerosol delivery nebuliser in children with Cystic Fibrosis. *Journal of Cystic Fibrosis* 2009. In Press.
 148. Latchford G, Duff A, Quinn J et al. Adherence to nebulised antibiotics in cystic fibrosis. *Patient education and counselling* 2009; 75:141-144.
 149. Daniels, TE, Goodacre, L, Sutton, C.J, Pollard, K, Watson, R, Conway, SP, Peckham, DP. Self & clinician assessment of adherence versus electronic monitoring of nebulisers in adults with Cystic Fibrosis. *Chest* 2010; in press.
 150. BTS guideline. Non-invasive ventilation in acute respiratory failure. *Thorax* 2002; 57:192-211.
 151. Moran F, Bradley J. Non-invasive ventilation for cystic fibrosis. *Cochrane Database Syst Rev* 2003; (2):CD002769. Chichester: Wiley InterScience, 2003.
 152. Holland AE, Denehy L, Ntoumenopoulos G. Non-invasive ventilation assists chest physiotherapy in adults with acute exacerbations of cystic fibrosis. *Thorax* 2003; 58:880-4
 153. Placidi G, Cornacchia M, Polese G, Zanolla L, Assael B, Braggion C. Chest physiotherapy with positive airway pressure: a pilot study of short-term effects on sputum clearance in patients with cystic fibrosis and severe airway obstruction. *Respiratory Care* 2006; 51(10):1145-53
 154. Fauroux B, Boule M, Lofaso F, et al. Chest physiotherapy in cystic fibrosis: improved tolerance with nasal pressure support ventilation. *Pediatrics* 1999; 103:E32.
 155. Madden BP, Kariyawasam H, Siddiqi AJ, et al. Noninvasive ventilation in cystic fibrosis patients with acute or chronic respiratory failure. *Eur Respir J* 2002; 19:310-13.
 156. Gozal D. Nocturnal ventilatory support in patients with cystic fibrosis: comparison with supplemental oxygen. *Eur Respir J* 1997; 10:1999-2003
 157. Milross MA, Piper AJ, Norman M, et al. Low-flow oxygen and bilevel ventilatory support: effects on ventilation during sleep in cystic fibrosis. *Am J Respir Crit Care Med* 2001; 163:129-34.
 158. Young, A.C., Wilson, J.W., Kotsimbos, T.C., Randomised placebo controlled trial of non-invasive ventilation for hypercapnia in Cystic Fibrosis. *Thorax* 2008; 63:72-77.
 159. Cornacchia M, Zenorini A, Perobelli S, Zanolla L, Mastella G, Braggion C. Prevalence of urinary incontinence in women with cystic fibrosis. *BJU Int* 2001; 88:44-48.
 160. Orr A, McVean RJ, Webb AK, Dodd ME. Questionnaire survey of urinary incontinence in women with cystic fibrosis. *BMJ* 2001; 322:1521.
 161. Nixon GM, Glazner JA, Martin JM, Sawyer SM. Urinary incontinence in female adolescents with cystic fibrosis. *Pediatrics* 2002; 110:e22.

162. Moran F, Bradley JM, Boyle L, Elborn JS. Incontinence in adult females with cystic fibrosis: a Northern Ireland survey. *Int J Clin Pract* 2003; 57:182-183.
163. Blackwell K, Malone PS, Denny A, Connett G, Maddison J. The prevalence of stress urinary incontinence in patients with cystic fibrosis: an under-recognized problem. *J Pediatr Urol.* 2005; 1:5-9.
164. Prasad SA, Balfour-Lynn IM, Carr SB, Madge SL. A comparison of the prevalence of urinary incontinence in girls with cystic fibrosis, asthma, and healthy controls. *Pediatr Pulmonol.* 2006; 41:1065-8.
165. Vella M, Cartwright R, Cardozo L, Parsons M, Madge S, Burns Y. Prevalence of incontinence and incontinence-specific quality of life impairment in women with cystic fibrosis. *Neurourol Urodyn.* 2009; 28:986-989.
166. Madge S & Agent P. Quality of life in women with cystic fibrosis and urinary incontinence. [abstract] *Journal of Cystic Fibrosis* 2008; 7:S100.
167. Gumery L, Lee J, Whitehouse J et al. The prevalence of urinary incontinence in adult cystic fibrosis males. [abstract] *Journal of Cystic Fibrosis* 2005; 4:S97.
168. McVean RJ, Orr A, Webb AK, Bradbury A, Kay L, Philips E, Dodd ME. Treatment of urinary incontinence in cystic fibrosis. *J Cyst Fibros.* 2003; 2:171-6.
169. Button BM, Sherburn M, Chase J et al. Effect of a three-month physiotherapeutic intervention on incontinence in women with chronic cough relate to cystic fibrosis and COPD. [abstract] *Pediatric Pulmonology* 2005; suppl 28 113:a369.
170. Helm JM, Langman H, Dodd ME, Ahluwalia A, Jones AM, Webb AK. A novel solution for severe urinary incontinence in women with cystic fibrosis. *J Cyst Fibros.* 2008; 7:501-504 .
171. Edenborough FP, Stableforth DE, Webb AK, et al. Outcome of pregnancy in women with cystic fibrosis. *Thorax* 1995; 50:170-174.
172. Edenborough FP, Borgo G, Knoop C, et al (2008). 'Guidelines for the management of pregnancy in women with cystic fibrosis', *Journal of Cystic Fibrosis* 7; S2-S32.
173. Thorpe-Beeston JG. Contraception and pregnancy in cystic fibrosis. *J R Soc Med* 2009; 102 (suppl 1):3-10.
174. Parrott H, Madge S, Thorpe-Beeston G, Agent P. 'Airway clearance requirements during pregnancy', *Pediatric Pulmonology*, 2008; S31:523.
175. Lamireau T, Monnereau S, Martin S, Marcotte JE, Winnock M, Alvarez F. Epidemiology of liver disease in cystic fibrosis: a longitudinal study. *J Hepatol.* 2004 Dec; 41(6):920-5.
176. Colombo C, Apostolo MG, Ferrari M, et al. Analysis of risk factors for the development of liver disease in CF. *J Pediatr* 1994; 124: 393-399.
177. Duthie A, Doherty DG, Williams C, Scott-Jupp R, Warner JO, Tanner MS, Williamson R, Mowat AP. Genotype analysis for delta F508, G551D and R553X mutations in children and young adults with cystic fibrosis with and without chronic liver disease. *Hepatology* 1992; 15(4):660-4.
178. The Leeds Method of Management. April, 2008. Cystic fibrosis and liver disease [online]. Leeds Regional Adult and Paediatric Cystic Fibrosis Units, St James's University Hospital, Leeds, UK. Available from <http://www.cysticfibrosismedicine.com>.
179. Kashani A, Landaverde C, Medici V, Rossaro L. Fluid retention in cirrhosis: pathophysiology and management. *Qjm*, Feb 2008, vol./is. 101/2(71-85), 1460-2725.
180. Roebuck D J. Barnacle AM. Mini-symposium: Imaging and Interventional Radiology.

- Haemoptysis and bronchial artery embolisation in children. *Paediatric Respiratory Reviews* 2008; 9:95-104.
181. Barben JU, Ditchfield M, Carlin JB, Robertson CF, Robinson PJ, Olinsky A. Major haemoptysis in children with cystic fibrosis: a 20-year retrospective study. *Journal of Cystic Fibrosis* 2003; 2: 105-111.
 182. Furnari ML, Salerno S, Rabiolo A, Caravello V, Pardo F. Case report: Bronchial to subclavian shunt in a CF patient. A potential pitfall for embolisation. *Journal of Cystic Fibrosis* 2003; 2: 217-219.
 183. Efrati O, Harash O et al. Hemoptysis in Israeli CF patients – Prevalence, treatment, and clinical characteristics. *Journal of Cystic Fibrosis* 2008; 7:301-306.
 184. Flume PA, Yankaskas JR, Ebeling M, Hulsey T, Clark LL, Massive Hemoptysis in Cystic Fibrosis. *Chest* 2005; 128:729-738.
 185. Marshall TJ, Flower CDR, Jackson JE. Review: The Role of Radiology in the Investigation and Management of Patients with Haemoptysis. *Clinical Radiology* 1996; 51:391-400.
 186. Ibrahim WH. Massive haemoptysis: the definition should be revised. *Eur Respir J* 2008; 32:1131-1132
 187. Flume PA. Pulmonary Complications of Cystic Fibrosis. *Respiratory Care* 2009; 54(5):618-627.
 188. Macduff A, Arnold T, Harvey J. BTS Draft Guidelines for the Management of Spontaneous pneumothoraces 2009 <http://www.brit-thoracic.org.uk/clinical-information/pleural-disease/draft-guidelinespleural-disease.aspx>.
 189. Cuenca AG, Beierle E A. Pulmonary surgery in cystic fibrosis. *Seminars in Pediatric Surgery* 2008; 17:60-65 .
 190. Curtis HJ, Bourke SJ, Dark JH, et al. Lung transplantation outcome in cystic fibrosis patients with previous pneumothorax. *J Heart Lung Transplant* 2005; 24:865-9.
 191. Robinson P D, Cooper P, Ranganathan S C. Evidence-based management of paediatric primary spontaneous pneumothorax. *Paediatric Respiratory Reviews* 2009; 10:110-117.
 192. MacDuff A, Tweedie J, McIntosh L, Innes J.A. Pneumothorax in cystic fibrosis: Prevalence and outcomes in Scotland. *J Cyst Fibros* 2010; 9(4):246-249.
 193. Flume PA, Strange C, Ye X, et al. Pneumothorax in cystic fibrosis. *Chest* 2005; 128:720-8
 194. Henry M, Arnold T, Harvey J. BTS guidelines for the management of spontaneous pneumothorax. *Thorax* 2003; 58(suppl II):39-52.
 195. Hafen GM, Ukoumunne OC, Robinson PJ. Pneumothorax in cystic fibrosis: a retrospective case series. *Arch Dis Child* 2006; 91:924-925.
 196. Dicken BJ, Ziegler MM. Surgical management of pulmonary and gastrointestinal complications in children with cystic fibrosis. *Current Opinion in Pediatrics* 2006; 18:321-329.
 197. Schuster SR, McLaughlin J, Matthews WJ, et al. Management of pneumothorax in adults with cystic fibrosis. *J Pediatr Surg*. 1983; 18:492-7.
 198. Tschopp JM, Rami-Porta R, Noppen M, Astoul P. Management of spontaneous pneumothorax: state of the art. *European Respiratory Journal* 2006; 28:637-650
 199. Flume PA. Pneumothorax in cystic fibrosis. *Chest* 2003; 123(1):217-221.
 200. Ellafi M, Vinsonneau C, Coste J et al. One-year outcome after severe pulmonary exacerbation in adults with cystic fibrosis. *Am J Respir Crit Care Med* 2005; 171(2):158-64.
 201. Sood N, Paradowski LJ, Yankaskas JR. Outcomes of intensive care unit care in adults with

- cystic fibrosis. *Am J Respir Crit Care Med* 2001; 163(2):335-8.
202. Texereau J, Jamal D, Choukroun G et al. Determinants of mortality for adults with cystic fibrosis admitted in intensive care unit : a multicentre study. *Respir Res.* 2006; 7:14.
 203. Efrati O, Bylin I, Segal E et al. Outcome of patients with cystic fibrosis admitted to the intensive care unit: is invasive mechanical ventilation a risk factor for death in patients waiting lung transplantation? *Heart Lung* 2010; 39(2):153-9.
 204. Vedam H, Moriaty C, Torzillo PJ et al. Improved outcomes of patients with cystic fibrosis admitted to the intensive care unit. *J Cyst Fibros* 2004; 3(1):8-14.
 205. Maury G, Langer D, Verleden G et. al. Skeletal muscle force and functional exercise tolerance before and after lung transplantation: A cohort study. *American Journal of Transplantation* 2008; 8:1275-1281.
 206. Langer D, Gosselink R, Pitta F et. al. Physical activity in daily life 1 year after lung transplantation. *Journal of Heart and Lung Transplantation* 2009; (28)6:572-578.
 207. Munro P, Holland A, Bailey M, Button B, Snell G. Pulmonary rehabilitation following lung transplantation. *Transplantation Proceedings* 2009; 41:292-295.
 208. Wickerson L, Mathur S, and Brooks D. Exercise training after lung transplantation: A systematic review. *Journal of Heart and Lung Transplantation* 2010; 29(5):497-503.
 209. Oelberg D, Systrom D, Markowitz D et. al. Exercise performance in cystic fibrosis before and after bilateral lung transplantation. *Journal of Heart and Lung Transplantation* 1998; 17(11):1104-1112.
 210. Robinson WM, Ravilly S, Berde C et al. End of life care in cystic fibrosis. *Paediatrics* 1997; 100:205-9.
 211. Liou TG, Adler FR, Fitzsimmons SC et al. Predictive survivorship model of cystic fibrosis. *Am J Epidemiol* 2001; 153:345-52.
 212. Agent P & Tonkin V. A retrospective analysis of physiotherapy input during a standard admission compared to a terminal admission in adults with CF. *J of CF* 2007; 6(suppl 1):S63.
 213. Agent P & Tonkin V. Physiotherapy adaptations in end of life care in adults with cystic fibrosis – a retrospective analysis. *Ped Pulm* 2006; 41; S29:A399.

II. GLOSSARY OF ABBREVIATIONS

AAD	Adaptive aerosol delivery
ACBT	Active cycle of breathing techniques
ACPCF	Association of Chartered Physiotherapists in Cystic Fibrosis
ACT	Airway clearance techniques
AD	Autogenic drainage
BAE	Bronchial artery embolisation
BTS	British Thoracic Society
CF	Cystic fibrosis
CFALD	Cystic fibrosis associated liver disease
CFQ-R	Cystic fibrosis questionnaire – Respiratory
COPD	Chronic obstructive pulmonary disease
CT	Computed tomography
FEF ₂₅₋₇₅	Forced expiratory flow (25-75)
FET	Forced expiration technique
FEV ₁	Forced expiratory volume in 1 second
FRC	Functional residual capacity
FVC	Forced vital capacity
GORD	Gastro-oesophageal reflux disease
GRADE	Grading of Recommendations Assessment, Development & Evaluation
HFCWC	High frequency chest wall compression
HFCWO	High frequency chest wall oscillation
IPPB	Intermittent positive pressure breathing
IPV	Intrapulmonary percussive ventilation
MRSA	Methicillin-resistant <i>Staphylococcus aureus</i>
NIV	Non-invasive ventilation
PD	Postural drainage
PEEP	Positive end expiratory pressure
PEP	Positive expiratory pressure
QoE	Quality of evidence
SIGN	Scottish Intercollegiate Guidelines Network
UI	Urinary incontinence
VAS	Visual analogue scale
VATS	Video-assisted thoracoscopic surgery
VMT	Vibrating mesh technology

APPENDIX I

Physiotherapy Management of Screened Infants with CF

Physiotherapy guidance paper

The ACPCF have released a number of guidance papers. These papers have been written and approved by members of the ACPCF committee and ACPCF protocols working group.

Wherever possible, experts within a particular area have been consulted and contributed to a paper. Reference is made to the literature on the subject, but a rigorous protocol with thorough review of the literature may not have been undertaken. These papers should therefore be considered as an aid to clinical practice and not as a definitive protocol for a given topic.

Date of Issue: October 2008

Authors: Ammani Prasad, Elaine Dhouieb

Contact details: PRASAA@gosh.nhs.uk

Contributors: Penny Agent, Katie Ferguson, Mary Dodd, ACPCF Committee

Contents: Introduction, Literature Review, Formulation of Clinical Guidance, References, Recommendations for practice.

Appendix 1 Parent Assessment Tool

Appendix 2 Physical Activity in Infants with CF

Appendix 3 Airway Clearance Techniques

ACPCF Physiotherapy Guidance Paper no. 4

Clinical Guidance for the Physiotherapy Management of Screened Infants with Cystic Fibrosis

Clinical Guidance for the Physiotherapy Management of Screened Infants with Cystic Fibrosis

Introduction

These guidelines have been compiled to complement the Delphi Consensus on Physiotherapy Management of Asymptomatic Infants with Cystic Fibrosis (CF).¹ Babies born with CF have essentially normal lungs but within variable time scales develop chronic respiratory disease which will ultimately be fatal in the majority of patients. With the recent introduction of newborn screening throughout the UK babies are diagnosed with CF soon after birth, often before they have any symptoms or lung pathology. Additionally, babies with mild mutations who may not have become symptomatic until adult life, are also being diagnosed in infancy. This means that there is now a cohort of infants who present to CF Centres at a very young age and often with no signs or symptoms of disease. Over the last two decades, the importance of early intervention has been recognised,^{2,3} and most CF Centres have adopted a policy of close monitoring and aggressive treatment of early lung disease. A significant number of children with CF now have normal lung function well into early adulthood even though they are very likely to have underlying lung pathology.⁴ Traditionally in the UK, chest physiotherapy has been instigated at diagnosis, consisting of twice daily postural drainage (PD) using a head down tip combined with chest wall percussion. Many babies and young children presenting to CF Centres now display no overt signs of respiratory disease and have good nutritional status with body mass index (BMI) within normal limits. Specialist physiotherapists in the UK caring for these babies have begun to question the role of traditional, routine airway clearance in these

‘asymptomatic’ babies. While health professionals agree unanimously that physiotherapy interventions are appropriate once respiratory symptoms are apparent,^{5,6} the place of routine daily airway clearance prior to this is less clear. It is also recognised that while infants may be asymptomatic at diagnosis they may over a given time span, swing along a spectrum of being asymptomatic at times and symptomatic at others. How this should be dealt with in terms of routine airway clearance is also not established. A review of patients and families by the CF Trust reported that chest physiotherapy is considered a large burden of care. Families wish to know if routine treatment is necessary in those babies with few or no symptoms.⁷ Physiotherapists have a duty to provide safe and effective care and daily treatment regimens need to be tailored to individual needs, lifestyle and symptoms, particularly as long-term routine ACT is seen as a substantial burden for patients and families.⁷ With these apparently asymptomatic babies the dilemma now facing physiotherapists is whether it is necessary to recommend daily routine airway clearance, and if so then which airway clearance technique (ACT) is most appropriate. There is currently no evidence addressing these questions and the issue of whether routine airway clearance is necessary has generated considerable international debate. Present circumstances preclude a rigorous clinical trial in the UK.¹

Arguments for early commencement of physiotherapy in symptom free babies are three-fold. Firstly, there is good evidence that early lung disease precedes the development of overt symptoms in children with CF.^{2,8-14} Secondly, anatomical and physiological differences, which result from immaturity of the respiratory system, in combination with CF, render the CF infant more vulnerable than the older child to respiratory complications and infection.

Finally, establishing daily routines early in a life-long illness is thought to facilitate acceptance of the need for treatment and adherence on the part of both the child and family. It may also enable parents to maintain their competency in airway clearance techniques¹⁵⁻¹⁷. Conversely, the presence of bacterial infection and raised inflammatory markers reported from BAL is not always associated with excessive sputum production or symptoms that respond to airway clearance. There is no physiological argument or scientific proof that physiotherapy is helpful in alleviating the inflammatory process within the airways. It is well known that adherence to routine therapy in chronic disease poses a significant problem and that when the benefit of a treatment is not immediately apparent, adherence is often poorest.¹⁸⁻²¹

Literature review

There is good evidence that babies may have respiratory involvement even when well on clinical examination and showing no overt symptoms. Sophisticated investigative techniques such as infant lung function, bronchoalveolar lavage (BAL) and high resolution computed tomography (HRCT) show that early changes are present from an early age.

Bronchoalveolar lavage

Kahn et al reported airway inflammation to be present in infants as young as four weeks (increased IL-8 levels and neutrophils) from bronchoalveolar lavage fluid (BALF) of 16 infants diagnosed with CF through a state wide neonatal screening programme.⁸ Levels were increased even in some infants who had negative cultures for common CF-related bacterial pathogens. Armstrong et al reported that *Staphylococcus aureus* was present in BALF of almost 40% of CF infants (14/45), more than one third of whom were symptom free.⁹ Although respiratory pathogens were found to be an important cause of inflammation, not all infected subjects had inflammatory cells or symptoms. This study also suggested that infection was overestimated by throat cultures, suggesting that for many subjects bacterial pathogens remain confined to the upper airways. Rosenfeld et al studied 40 CF infants over a two year period and reported an increase in CF pathogens with age.² Infants had elevated markers of inflammation whether CF pathogens were recovered or not, although the concentrations of these

markers increased with the density of CF pathogens in BALF. These infants were also reported to have obstructive lung disease (expiratory flows and air trapping). Nixon et al investigated the relationship between lower airway infection and inflammation, respiratory symptoms and lung function in infants and young children with cystic fibrosis diagnosed by newborn screening.²² Thirty-six children (<3yrs) underwent BAL and lung function testing. Lower airway infection was associated with a significant reduction in lung function. Although a daily moist cough within the week before testing was reported on 20/54 testing occasions, infection was only detected in only seven samples. Children with a daily cough had lower lung function than those without respiratory symptoms at the time of BAL. The authors concluded that both respiratory symptoms and airway infection have independent additive effects on lung function (unrelated to airway inflammation). The presence of a moist daily cough in young children with mild CF lung disease is independently associated with a reduction in lung function. In a retrospective review of a non newborn screened population Hilliard et al reported the presence of *P. aeruginosa* in 20% (5/25) and *S. aureus* in 16% (4/25). The median age of the study population was 12 months and lavage culture was reported to be positive in eight out of 18 asymptomatic children.²³

Lung function

Lung function abnormalities in infants with CF have been reported from as early as 1988.²⁴⁻²⁵ Measurements of airway function in non screened newly diagnosed infants made soon after diagnosis and then repeated six months later were reported by Ranganathan et al.¹¹ After adjusting for age, length, sex and exposure to maternal smoking, the authors reported a significant reduction in FEV_{0.5} both soon after diagnosis and on repeat testing six months later. This study implies that airway function is diminished in a non-screened population soon after diagnosis and the reduction persists during infancy.

Lung clearance index (LCI), is a measure of ventilation inhomogeneity which is derived from a multiple-breath inert gas washout (MBW) technique. Lum et al studied³⁹ non-screened infants using MBW to measure LCI along side measures of other airway function.²⁶ Using both techniques, abnormalities were detected in 72% of infants (41% of abnormalities were detected by both techniques and a further 15% by each of the two tests performed). Kozłowska et al reported findings of a longitudinal study of 48 children (non-screened, but managed at a Specialist CF Centre) with CF and 33 healthy controls.¹³ Over these early years, the diagnosis of CF itself accounted for a significant reduction in FEV_{0.75} and FEF₂₅₋₇₅. Wheeze on auscultation, recent cough, and *Pseudomonas aeruginosa* infection (even if apparently effectively treated) were all independently associated with further reductions in lung function. This study demonstrated that CF per se, in the absence of complications, is associated with decreased lung function and specialist treatment does not appear to ameliorate this, implying that new treatments are needed to improve lung health.

Computed tomography of the chest

There are many studies which show early inflammation and air trapping in infants with CF. Martinez et al showed that infants with CF have thickened airway walls, narrowed airway lumens and air trapping compared with controls in high resolution computed tomography.¹⁴ These measurements correlated with airway function. However it is unclear which if any of these changes ACT will influence.

Adherence

The argument for establishing a daily routine to optimise adherence is not established. Non-adherence to treatment regimens in chronic disease has been reported to be as high as 50%.¹⁸⁻²⁰ Time-consuming interventions which have no immediately palpable benefit and those interventions

which cause disruption to lifestyle are associated with poorer rates of adherence.¹⁹⁻²¹ It has also been suggested that insistence on routine daily treatment may even reduce adherence during the adolescent years when the need for treatment may become greater.²⁷

Physiotherapy

One of the dilemmas for CF physiotherapists is when and what treatment to teach parents and carers of asymptomatic infants diagnosed by newborn screening. There is clear evidence to suggest early lung disease is present even in the absence of symptoms and it is widely accepted that early and aggressive treatment of lung disease is essential. However, the early pathophysiological changes are not always associated with signs or symptoms that respond to airway clearance. If these “asymptomatic” babies are carefully monitored and have no apparent chest pathology which responds to airway clearance, what is the place of daily routine airway clearance have in this cohort? Also if inflammation plays a significant role in early lung disease, can ACT have any role in alleviating this process? Conversely if infection, with likely sputum production is part of the early pathological picture then early institution of airway clearance would appear sensible. There is nothing in the current literature which addresses these specific issues but some studies are relevant to this topic.

A systematic review comparing chest physiotherapy to no chest physiotherapy in CF has been undertaken by Van der Schans et al.²⁸ In a comprehensive search 126 randomised controlled trials were identified but only six studies were eligible for inclusion in the review, due mainly to methodological issues, such as the lack of a “no treatment” control population. Even the included studies scored poorly in terms of methodological quality (using the Jadad scoring system²⁹), mainly because two of the items scored are blinding and in physiotherapy studies it is impossible to blind both investigator and subject to the intervention. Due to high variability of outcome measures meta-analysis was not possible and the authors could not draw any conclusions with regard to the long-term effects of chest physiotherapy in CF. However the results of this review indicated that airway clearance techniques have short-term effects in the terms of increasing mucus transport.

Very few studies examine the effects of chest physiotherapy in children specifically. Desmond et al evaluated the effects of chest physical therapy in eight children with CF.³⁰ Spirometric measures of lung function were compared from baseline to the end of a three week period without chest physical therapy with measurements at baseline and the end of a period of chest physiotherapy on a twice daily basis. The authors reported deterioration in lung function following the three-week period without treatment, which was reversed with resumption of treatment. The immediate effect of four modes of treatment on lung function in 19 infants was assessed by Maayan et al during the first year of life.³¹ The regimens were applied in a randomised fashion (inhaled salbutamol, inhaled N-acetyl cysteine, chest physiotherapy; or a combination of all three). No significant changes in lung volumes were reported in individual groups but there was a small improvement with the combined treatment group when compared with inhalation therapy or chest physiotherapy alone. Both of these studies are now over twenty years old and therefore relate to a very different population of infants and none were carried out in asymptomatic infants.

More recently Constantini et al compared the long-term efficacy of PEP mask versus postural drainage and percussion in infants with CF. There was no difference in deterioration on chest radiograph or days per year of antibiotics over a one year period.³² The authors concluded that PEP was safe to use in early childhood and equally effective as postural drainage and percussion, although patients and parents preferred PEP. In Sweden significant changes were made to the physiotherapy management of patients with CF at the beginning of the 1980s from postural drainage and percussion or active cycle of breathing techniques (ACBT) to an individually tailored programme of physical activity, inhalation therapy and airway clearance.³³ Dennersten et al reported the lung function of their patient population (seven years or older) over a three-year period, with a median

FEV₁ of 93% in the 7–12 year old age group, concluding that their management regimen showed good results.³⁴

The issue of gastro-oesophageal reflux (GOR) has received much attention over the past decade. Button et al demonstrated that GOR increased in physiotherapy regimens which used postural drainage incorporating a head down tilt when compared with regimens which used a modified postural drainage (omitting any head down tilt).³⁵⁻³⁶ Long-term follow up of these infants also reported fewer respiratory complications in the group receiving modified postural drainage.³⁷ Despite weaknesses in these studies (in particular with regard to subject numbers), the potentially detrimental effects of postural drainage raised have led many to recommend that the head-down tipped position should no longer be used in infants during airway clearance regimens.³⁸

In a prospective randomised controlled study, Dhouieb et al investigated the effect of a single airway clearance session (ACBT) compared with a control group on LCI, FEV₁ and FRC in 18 children with CF (12m; 6f), mean age 11.94 years (7–17yrs).³⁹ There were no statistically significant differences in any of the outcome measures between the groups. However, the treatment group showed an increase in LCI. This increase may be due to changes in ventilation and movement of secretions resulting from the airway clearance session. The rise is likely to be temporary but larger numbers are required to investigate the effect of ACTs on LCI.

Formulation of clinical guidance

The literature to date does not provide us with clear evidence as to who may benefit from routine ACTs and whether those who have no symptoms require routine daily airway clearance. Prasad and Main²⁷ stated:

“However, in the era of evidence-based medicine, adopting new approaches without a substantial evidence base risks the loss of potentially beneficial elements of traditional treatments.”

The best way to address this issue would be to undertake a prospective randomised control trial comparing twice daily routine airway clearance with a regimen of close monitoring and airway clearance on a p.r.n basis. However, present circumstances preclude a rigorous clinical trial in the UK.¹ In view of this, the absence of any robust scientific evidence and the concerns of some physiotherapists, the Association for Chartered Physiotherapists in CF conducted a Delphi consensus exercise amongst specialist physiotherapists in the UK, in order to formulate guidelines for the management of infants with cystic fibrosis diagnosed by newborn screening. The Delphi technique is a consensus method which can be applied to situations where published information is non-existent or inadequate.⁴⁰ It is used to canvas opinion and to make structured decisions using a multiple postal survey technique to gather and refine expert opinion on any given issue. It has been widely used within the nursing and allied health professions. The results of this process showed that there was a very high consensus of opinion amongst senior physiotherapists in the UK on most aspects of the physiotherapy management of babies with cystic fibrosis. However, consensus could not be achieved on whether routine daily chest physiotherapy is necessary in ‘asymptomatic’ babies.

The issue of routine daily airway clearance remains contentious. While most physiotherapists agreed that a rigid twice a day prescription of airway clearance is often no longer needed, some were reluctant to advise that airway clearance was not necessary on a daily basis. An agreed amendment to the original statement allows the individual practitioner to make this judgement on an individual patient basis with the sanction of a professional body. The wording of the guidelines reflects this agreed amendment to the single statement which did not achieve consensus during the process. The results of this process have been used to form the basis of the following clinical practice guidance.

REFERENCES

1. Prasad SA, Main E, Dodds M E. Finding Consensus on the Physiotherapy Management of asymptomatic Infants with CF. *Pediatric Pulmonology* 2008; 43:236-244.
2. Rosenfeld M, Gibson RL, McNamara S, Emerson J, Burns JL, Castile R, Hiatt P, McCoy K, Wilson CB, Inglis A, Smith A, Martin TR, Ramsey BW. Early pulmonary infection, inflammation and clinical outcomes in infants with cystic fibrosis. *Pediatr Pulmonol* 2001; 32:356-366.
3. Sims EJ, Clark A, McCormick J, Mehta G, Connett G, Mehta A. United Kingdom Database Steering Committee. Cystic fibrosis diagnosed after two months of age leads to worse outcomes and requires more therapy. *Pediatrics* 2007; 119:19-28
4. Tiddens HA. Detecting early structural lung damage in cystic fibrosis. *Pediatric Pulmonology* 2002; 34:228-231
5. Robinson P. Cystic fibrosis. *Thorax* 2001; 56:237-241.
6. Gibson RL, Burns JL, Ramsey BW. Pathophysiology and management of pulmonary infections in cystic fibrosis. *Am J Respir Crit Care Med* 2003; 168:918-951.
7. CF Trust. Strategic Review 'Project Life' 2000. CF Trust, Bromley, Kent, UK
8. Khan TZ, Wagener JS, Bost T, Martinez J, Accurso FJ, Riches DWH. Early pulmonary inflammation in infants with cystic fibrosis. *Am J Respir Crit Care Med* 1995; 151:1075-1082.
9. Armstrong DS, Grimwood K, Carzino R, Carlin JB, Olinsky A, Phelan PD. Lower respiratory infection and inflammation in infants with newly diagnosed cystic fibrosis. *BMJ* 1995; 310: 1571-1572.
10. Ranganathan SC, Dezateux C, Bush A, Carr SB, Castle RA, Madge S, Price J, Stroobant J, Wade A, Wallis C, Stocks J, London Collaborative Cystic Fibrosis Group. Airway function in infants newly diagnosed with cystic fibrosis. *Lancet* 2001;358: 1964–1965.
11. Ranganathan SC, Stocks J, Devateux C, Bush A, Wade A, Carr S, Castle R, Dinwiddie R, Hoo AF, Lum S, Price J, Stroobant J, Wallis C. The evolution of airway function in early childhood following clinical diagnosis of cystic fibrosis. *Am J Respir Crit Care Med* 2004; 169:928-933.
12. Aurora P, Kozłowska W, Stocks J. Gas mixing efficiency from birth to adulthood measured by multiple-breath washout. *Respir Physiol Neurobiol* 2005; 148:125-139.
13. Kozłowska WJ, Bush A, Wade A, Aurora P, Carr SB, Castle RA, Hoo A, Lum S, Price J, Ranganathan S, Saunders C, Stanojevic S, Stroobant J, Wallis C, Stocks J, on behalf of the London Cystic Fibrosis Collaboration. Lung Function from Infancy to the Preschool Years following Clinical Diagnosis of Cystic Fibrosis. *American Journal of Respiratory and Critical Care Medicine* 2008; 178:42-49
14. Martinez TM, Llapur CJ, Williams TH, Coates C, Gunderman R, Cohen MD, Howenstine MS, Saba O, Coxson HO, Tepper RS. High-resolution computed tomography imaging of airway disease in infants with cystic fibrosis. *Am J Respir Crit Care Med* 2005; 172:1133-1138.
15. Lannefors L, Button BM, McIlwaine M. Physiotherapy in infants and young children with cystic fibrosis: current practice and future developments. *J R Soc Med* 2004; 97:8-25.
16. (a)Lemons PM, Weavers DD. Beyond the birth of a defective child. *Neonatal Netw* 1987; 5:13-2015. (b)Myer PA. Parental adaptation to cystic fibrosis. *J Pediatr Health Care* 1998; 2:20-28.
17. Jedlicka-Kohler I, Gotz M, Eicher I. Parents' recollection of the initial communication of the diagnosis of cystic fibrosis. *Pediatrics* 1996; 97:204-209.
18. Finney JW, Hook RJ, Friman PC, Rapoff MA, Christophersen ER. The overestimation of

- adherence to pediatric medical regimens. *Child Health Care* 1993; 22:297-304.
19. Czajkowski DR, Koocher GP. Medical compliance and coping with cystic fibrosis. *J Child Psychol Psychiatry* 1987; 28:311-319.
 20. Bryon M. Adherence to treatment in children. In: Myers L, Midence K, editors. *Adherence to treatment in medical conditions*. Oxford: Harwood; 1996. pp. 161-189.
 21. Gudas LJ, Koocher GP, Wypij D. Perceptions of medical compliance in children and adolescents with cystic fibrosis. *J Dev Behav Pediatr* 1991; 12:236-242.
 22. Nixon G M et al. Early airway infection, inflammation and lung function in CF. *Archives of Diseases of Childhood* 2002; 87:306-311.
 23. Hilliard TN, Sukhani S, Francis J, Madded N, Rosenthal M, Balfour-Lynn I, Bush A, Davies JC. Bronchoscopy following diagnosis with cystic fibrosis. *Arch Dis Child* 2007; 92:898-899
 24. Beardsmore CS, Bar-Yishay E, Maayan C, Yahav Y, Katznelson D, Godfrey S. Lung function in infants with cystic fibrosis. *Thorax* 1988; 43:545-51.
 25. Tepper RS, Montgomery GL, Ackerman V, Eigen H. Longitudinal evaluation of pulmonary function in infants and very young children with cystic fibrosis. *Pediatr Pulmonol* 1993; 16:96-100.
 26. Lum S, Gustafsson P, Ljungberg H, Hulskamp G, Bush A, Carr S, Castle R, Hoo A, Price JF, Ranganathan S, Stroobant J, Wade A, Wallis C, Wyatt H, Stocks J, London Cystic Fibrosis Collaboration. Detection of cystic fibrosis lung disease: multiple-breath washout vs raised volume tests. *Thorax* 2007; 62:341-7.
 27. Prasad S A and Main E. Routine airway clearance in asymptomatic infants and babies with cystic fibrosis in the UK: obligatory or obsolete? *Physical Therapy Reviews*. 2006 Mar; 11(1): 11-20.
 28. Van der Schans C et al. Chest physiotherapy compared to no chest physiotherapy for CF. *Cochrane Library (Oxford)* 2005; (4): 0011401
 29. Jadad A R et al. Assessing the quality of reports of randomised clinical trials: is blinding necessary? *Controlled Clinical Trials* 1996; 17:1-12
 30. Desmond KJ, Schwenk WF, Thomas E, Beaudry PH, Beaudry, Coates AL. Immediate and long-term effects of chest physiotherapy in patients with cystic fibrosis. *Journal of Paediatrics* 1983; 103:538-542
 31. Maayan C, Bar-Yishay E, Yaacobi T, Marcus Y, Katznelson D, Yahav Y, Godfrey S. Immediate effect of various treatments on lung function in infants with cystic fibrosis. *Respiration* 1989; 55:144-151
 32. Constantini D, Brivio A, Brusa D, Delfino R, Fredella C, Russo M, Sguera A, Moretti E. PEP-Mask versus postural drainage in CF infants. A long-term comparative trial. *Pediatric Pulmonology* 2001; (Suppl 22):A400
 33. Lannefors L, Dennersten U, Theander K, Jartensson J, Kornfalt R. Successful treatment of infants and small children. *J Cystic Fibrosis* 2003; 2:S65-S250.
 34. Dennersten U, Lannefors L, Johansson H, Andersson M, Sellberg M, Lagerkvist A, Sahlberg M. Lung function and peak working capacity in the entire Swedish population ≥ 7 years old over a three years period. *Pediatric Pulmonology* 2003; (Suppl 25):A411.
 35. Button BM, Heine RG, Catto Smith AG, Postural drainage and gastro-oesophageal reflux in infants with cystic fibrosis. *Archives of Disease in Childhood* 1997; 76:148-150.
 36. Heine RG, Button BM, Olinsky A, Phelan PD, Catto-Smith AG. Gastro-oesophageal reflux in

- infants under 6 months with cystic fibrosis. Arch Dis Child. 1998 Jan; 78(1):44-8.
37. Button BM, Heine RG, Catto-Smith AG, Olinsky A, Phelan PD, Ditchfield MR, Story I. Chest physiotherapy in infants with cystic fibrosis: to tip or not? A five-year study. Pediatr Pulmonol 2003; 35:208-13.
 38. Orenstein DM. Heads up! Clear those airways! Pediatr Pulmonol 2003; 35:160-161.
 39. Dhouieb E. Evaluation of Lung Clearance Index as an Outcome Measure in Airway Clearance in Children with Cystic Fibrosis. MSc Dissertation 2007.
 40. Jones J, Hunter D. Consensus methods for medical and health services research. BMJ 1995; 311:376-380.

Recommendations for practice

Grading scheme for recommendations

The criteria used for the grading of the recommendations below are based on published on behalf of the Scottish Intercollegiate Guidelines Network.¹

Grade Type of recommendation

A – Requires at least one randomised controlled trial as part of the body of literature of overall good quality and consistency addressing the specific recommendation

B – Requires availability of well conducted clinical studies but no randomised clinical trials on the topic of the recommendation

C – Requires evidence from expert committee reports or opinions and/or clinical experience of respected authorities. Indicates absence of directly applicable studies of good quality.

Petrie GJ, Barnwell E, Grimshaw J, on behalf of the Scottish Intercollegiate Guidelines Network. Clinical guidelines: criteria for appraisal for national use. Edinburgh: Royal College of Physicians, 1995.

Recommendations

- *On confirmation of diagnosis, all families with newly diagnosed infants with cystic fibrosis should be referred for physiotherapy. Initial physiotherapy tuition should always be given by a Specialist CF Physiotherapist (Standards for the Clinical Care of Children and Adults with Cystic Fibrosis in the UK 2001). <http://www.cftrust.org.uk/aboutcf/publications/consensusdoc> [C].*
- *The infant should be reviewed on a regular basis by a physiotherapist with experience in paediatric CF care. An easily accessible physiotherapy service for assessment, advice and support is essential. Direct contact numbers for the CF physiotherapist should be available to the parents/carers, multidisciplinary teams and to the primary care and network care teams as appropriate [C].*
- *All parents/carers should be taught to assess signs and symptoms, using a structure respiratory assessment tool as appropriate (Appendix 1) [C].*
- *The emphasis should be on a holistic approach to treatment, considering the fitness of the whole child [C].*
- *The beneficial effects of exercise are well documented. Advice regarding positioning, movement and exercise programmes should begin from diagnosis (Appendix 2) [C].*

- *Even if the baby is “asymptomatic”, all parents/carers should be taught to assess symptoms in addition to being taught an appropriate airway clearance technique [C].*
- *The physiotherapist is not required to routinely initiate airway clearance (Appendix 3) on diagnosis unless, following assessment, the infant or child has symptoms that respond to respiratory physiotherapy. The advice given to parents/carers as to the need for and frequency of treatment should be based on the specialist physiotherapist’s evaluation of individual circumstances [C].*
- *The use of a head down tilt with postural drainage should be carefully considered with regard to both its efficacy in infants with relatively few secretions and the potential for exacerbating gastro-oesophageal reflux. If required, the use of modified chest physiotherapy, omitting the head down tilt may be more appropriate [B].*
- *When airway clearance (Appendix 3) is required parents/carers should be advised as to the type and frequency of treatment needed, based on clinical status. Families/carers should be fully involved in this decision process. A more prescriptive physiotherapy regimen may be appropriate for some families who feel or seem unable to confidently assess their child’s chest [C].*

Appendix Ia

Parent Assessment Tool – Breathing assessment tool for parents/carers in CF

The aim of airway clearance/chest physiotherapy is to clear secretions from the lungs and maintain normal lung function. Many babies when diagnosed with CF do not show any signs of a chest problem so it is important that you are familiar with the way your baby normally breathes. There are things you can see, feel and hear if your baby has secretions in the chest, or is unwell with a chest infection. Babies are unable to tell us when they are unwell, so it is important that you learn to recognise the signs. This is not difficult to do and parents very quickly learn to become familiar with recognising chest symptoms and knowing when to give treatment. The first step is to take the time to look at your baby with their vest/t-shirt off and familiarise yourself with the following:

- The colour of your baby’s skin and lips
- Movement of the chest as they breathe, looking at the shape of the chest and the ribs as they breath in and out and how fast they breathe
- The way the nostrils and head move as they breathe
- Whether they breathe through their nose or mouth and whether you can hear any sounds other than the air moving in and out, such as secretions rattling or wheezing
- The feel of the chest as they breathe
- The way your baby breathes when asleep and when awake
- Whether your baby coughs, and whether the cough is a “wet” or “dry” cough

Your physiotherapist will teach you to know what is normal, and you will learn to recognise changes, when to be concerned, and when you should carry out chest physiotherapy.

Use the assessment sheet overleaf to help you to assess any changes. It is important that you “practice” using this form when you are with your physiotherapist until you are confident and understand what you are looking for. As you become more confident, you will no longer need this sheet to help you.

It is very important that you take your baby to their GP or to your CF centre if you are worried. They will be happy to see your baby, answer any questions and address any concerns you may have.

Name and contact number

CF Physiotherapist:

CF Specialist nurse:

BREATHING ASSESSMENT CHECKLIST FOR PARENTS

STAGE 1 If the answer to either of the following questions is yes, it is important that you do carry out chest physiotherapy

Action

Yes No

Hear

Is he/she coughing?

Feel

Place hands around ribs – can you feel any secretions moving/rattling in the chest on breathing?

STAGE 2 Even if there is no obvious cough or rattle in the chest, it is still important to double check for some less obvious signs which might mean that there are some secretions in the chest or a chest infection. If the answer to one or more of the following questions is yes, it is still a good idea to give the baby some chest physiotherapy.

Action**Yes No****Observe**

Is breathing rate faster than normal? (Normal for baby under one year is 30–50 breaths per minute and baby one to two years 20–40 breaths per minute)

Are there signs of a cold e.g. snuffles or blocked nose?

Is your baby more unsettled/crying more than normal or do they seem to be unwell?

Does the skin feel warmer than usual (i.e. do you think he/she has a fever)?

Hear

Can you hear a wheeze (a musical noise usually on breathing out but may be on breathing in)

STAGE 3 If the answer to any of the following questions is “yes” your baby is very likely to require additional medication (e.g. antibiotics) as well as chest physiotherapy.

Action**Yes No****Observe**

Does the breathing look more laboured than usual? (vest/t-shirt off)

Can you see the ribs more clearly on breathing in? (Is the skin between the ribs sucked inwards on breathing in?)

Does the front of the chest, or the area below the ribs get “sucked inwards” on breathing in?

Are the nostrils flaring on breathing in?

Is the skin at the bottom of the neck sucked in on breathing in?

Does the head bob up and down on breathing?

Are the lips paler than normal?

Do the lips have a blue tinge? (If yes, you should urgently seek medical attention)

Hear

Are there any grunting noises on breathing?

Appendix Ib

Physical activity in infants with CF

The beneficial effects of exercise are well documented (CF Trust Physiotherapy guidelines), although no studies have formally investigated the value of early introduction of physical activity in babies with cystic fibrosis. The use of physical activity in babies with CF, in the form of positioning and movement have the following specific aims:

- Using positioning and movement to influence breathing pattern and utilise the effects of regional ventilation, redistributing ventilation in order to optimise ventilation to all areas of the lungs.
- Using movement to maintain mobility of the trunk, chest and spine.
- Using physical activity as part of “respiratory assessment”. Movement and “play” may make the presence of secretions apparent.

Appendix Ic

Airway clearance techniques

The term airway clearance represents a number of different treatment modalities which aim to enhance clearance of bronchopulmonary secretions. These may include breathing techniques such as assisted autogenic drainage, devices which deliver positive expiratory pressure and postural drainage and manual techniques.¹

Very few studies have evaluated airway clearance techniques in babies with cystic fibrosis.²⁻⁴ Techniques commonly used in the infant population are briefly described below but more detail can be found in the further reading list below.

Postural drainage

Gravity assisted positioning (postural drainage [PD]), using various positions to help drainage of secretions from particular areas of the lungs has traditionally been a major component of physiotherapy treatment of infants and young children with CF. The effects of gravity in enhancing airway clearance is likely to be a result not only of drainage but also of a change in distribution of ventilation.⁵

More recently, the use of a head down tip during postural drainage has been questioned due to concerns regarding gastro-oesophageal reflux.² Although the use of postural drainage remains very common in the treatment of infants and babies with cystic fibrosis, many Centres no longer incorporate a head-down tip but instead use a flat or slight head up positioning regimen (modified postural drainage).

Percussion (chest clapping)

Chest percussion or clapping again has been a mainstay of physiotherapy regimens in the younger CF population. Often combined with modified postural drainage it aims to mobilise secretions and stimulate cough.

Percussion is generally well tolerated and is widely used in infants. It is generally felt that it should be performed over a layer of clothing, using “tented” fingers or a cupped hand. In very small babies the use of a soft plastic cup shaped device (such as a face mask) may be helpful to administering the technique.

Positive expiratory pressure (PEP)

Positive expiratory pressure aims to facilitate airway clearance by increasing lung volume, opening up peripheral airways and enhancing collateral ventilation. The technique can be effectively applied in babies using an infant sized face mask and has been reported to be safe and as effective as postural drainage and percussion.⁴

Assisted autogenic drainage (AAD)

The use of this technique in babies has developed from AD in the older population. During assisted AD the therapist’s hands/arms are used to gently guide inspiration to the desired lung volume. No pressure is applied during expiration. Expiratory flow may be enhanced by combining the technique with bouncing on a gym ball. It is suggested that a session of treatment using any period of breathing at low lung volume should end with stimulation of breathing at a higher lung volume in order to re-

open airways and maximise ventilation.

Assisted expiratory manoeuvres

Compression of the thorax during expiration (similar to chest vibrations but without the oscillatory component) interspersed with bouts of physical activity (appendix Ib) can also be used as a treatment technique to mobilise airway secretions.⁶

References

1. Physiotherapy in the treatment of cystic fibrosis. International Physiotherapy Group for Cystic Fibrosis. <http://www.cfw.org/ipg-cf/>.
2. Button BM. Postural drainage techniques and gastro-oesophageal reflux in infants with cystic fibrosis. *Eur Respir J* 1999; 14:1456-1457.
3. Button BM, Heine RG, Catto-Smith AG, Olinsky A, Phelan PD, Ditchfield MR, Story I. Chest physiotherapy in infants with cystic fibrosis: to tip or not? A five-year study. *Pediatr Pulmonol* 2003; 35:208-213.
4. Constantini D, Brivio A, Brusa D, et al. PEP-mask versus postural drainage in CF infants: a long-term comparative trial. *Pediatr Pulmonol* 2001; A400.
5. Lannefors L, Wollmer P Mucus clearance with three chest physiotherapy regimes in cystic fibrosis: a comparison between postural drainage, PEP and physical exercise. *European Respiratory Journal* 1992; 5:748-753.
6. Lannefors L, Dennersten U, Theander K et al. Successful treatment of infants and children with cystic fibrosis. *J Cystic Fibrosis* 2003; 2(suppl 1):A250.

APPENDIX II

Exercise tests available

Exercise test	May be useful to:
Incremental cycle/treadmill ergometry <ul style="list-style-type: none"> • W_{peak} • VO_{2peak} (with gas exchange) • HR_{peak} • SpO_{2nadir} 	<ul style="list-style-type: none"> • Identify deficiency in cardiorespiratory fitness • Explore exertional signs symptoms e.g. breathlessness, desaturation or heart disease • Evaluation for lung transplant • Evaluation of interventions that aim to improve cardiorespiratory fitness • Prescription of specific training programme
Submaximal endurance cycle/treadmill ergometry <ul style="list-style-type: none"> • Endurance time • HR • SpO₂ 	<ul style="list-style-type: none"> • Identify deficiency in functional capacity • Evaluation of interventions that aim to improve functional capacity
Shuttle tests <ul style="list-style-type: none"> • Distance walked/run • HR_{peak} • SpO_{2nadir} 	<ul style="list-style-type: none"> • Identify deficiency in cardiorespiratory fitness • Evaluation for lung transplant • Evaluation of interventions that aim to improve cardiorespiratory fitness • Prescription of specific training programme
Walk Tests (e.g. 6 Minute Walk Test) <ul style="list-style-type: none"> • Distance walked • SOB/fatigue pre/post test • SpO₂ pre/post test 	<ul style="list-style-type: none"> • Identify deficiency in functional capacity • Evaluation for lung transplant • Evaluation of interventions that aim to improve functional capacity
3 Minute Step Test <ul style="list-style-type: none"> • number of steps performed • HR pre/post test • SpO₂ pre/post test • SOB/fatigue pre/post test 	<ul style="list-style-type: none"> • Explore exertional signs symptoms e.g. desaturation
WAnT <ul style="list-style-type: none"> o Peak power o Mean power o Fatigue index 	<ul style="list-style-type: none"> • Identify deficiency in muscle power • Evaluation of interventions that aim to improve muscle power • Prescription of specific training programme
1RM	<ul style="list-style-type: none"> • Identify deficiency in muscle strength • Evaluation of interventions that aim to improve strength • Prescription of specific training programme
Dynamometry	<ul style="list-style-type: none"> • Identify deficiency in muscle strength • Evaluation of interventions that aim to improve muscle strength • Prescription of specific training programme



Cystic Fibrosis Trust
11 London Road
Bromley
Kent BR1 1BY

Tel: 020 8464 7211

Fax: 020 8313 0472

enquiries@cftrust.org.uk

www.cftrust.org.uk

Reg Charity No 1079049
England and Wales

Reg Charity No SC40196
Scotland