

## PERSONAL VIEW

## Who needs chest physiotherapy? Moving from anecdote to evidence

Colin Wallis, Ammani Prasad

*“One case which I had was that of a newborn child with acquired atelectasis, which required my presence, or that of my assistant, for 24 hours. In such cases there is nothing, I believe, as efficacious as flagellation. I usually tell the attendant to take a rubber band and flip the soles of the feet whenever the child begins to tire of breathing.”*

Dr Sanders. In: Disturbances of respiration in the newborn. *Transactions of the American Pediatric Society* 1903;15:47.

At the beginning of this century, paediatrics was an art. Skills were learnt from a mentor, picking up tips and anecdotes while standing at your master's side. Now, as practitioners of child health in the final years of this same century, life has changed. Anecdote and word of mouth have lost credibility and are replaced by scientific scrutiny and the rigour of evidence from carefully controlled and sufficiently powerful trials. We do our best to find the truth, but in many areas of care there remains a dearth of sufficient evidence. Often in the closets of our own practices, we continue to do what our teachers taught us and what, over time, we believe works.

The central function of chest physiotherapy in paediatric respiratory disease is to assist in the removal of tracheobronchial secretions. The intention is to remove airway obstruction, reduce airway resistance, enhance gas exchange, and reduce the work of breathing. In the acute situation, recovery should be hastened and in the child with a chronic respiratory disorder, the progression of the lung disease is hopefully delayed.

Chest physiotherapy can improve a patient's respiratory status and expedite recovery. But in certain situations it may be a useless intervention or even harmful—perhaps by increasing bronchospasm, inducing pulmonary hypertension, repositioning a foreign body, or destabilising a sick infant. What good evidence have we accumulated to answer the question: who needs chest physiotherapy?

### Disorders with chronic sputum production

*“I have good results in these cases from pouring a small quantity of whiskey and water into the child's throat, some of which passed into the trachea and brought on coughing which was soon followed by good breathing.”*

Dr Booker. In: More timely use of intubation. *Transactions of the American Pediatric Society* 1905;17:139.

### CYSTIC FIBROSIS

Clearing bronchopulmonary secretions has long been an integral part of cystic fibrosis (CF) care. Physiotherapy techniques aim to remove excessive secretions, thereby improving ventilation in the short term. In the long term, reduction of elastase mediated damage to the airways might slow the progressive damage and impairment of mucociliary clearance.<sup>1</sup> A number of airway clearance techniques have been developed over the past few decades. Each hopes to achieve improved clearance for less effort and improve compliance, especially for the older independent child. Common techniques include a non-specific regimen of postural drainage and percussion (often termed “conventional” chest physiotherapy), the active cycle of breathing techniques,<sup>2</sup> autogenic drainage,<sup>3</sup> the use of oscillatory devices such as the flutter<sup>4</sup> or high frequency chest wall oscillator,<sup>5</sup> and the application of positive expiratory pressure.<sup>6</sup> But where is the evidence that physiotherapy improves lung disease in CF?

Early treatment was based on intuitive reasoning but its universal acceptance makes it ethically precarious to attempt the controlled trial of treatment versus no treatment in the child with established disease or even in the newly diagnosed infant. Thus, most trials involve the comparison of treatment types.<sup>7–10</sup> Publications are fraught with the difficulties of study design in physiotherapy trials and the inconsistency of findings leave the practitioner none the wiser in their search for an evidence base.<sup>11</sup> A meta-analysis of randomised trials in CF comparing the differing techniques with standard treatment showed no difference between them but did show significantly greater sputum expectoration than no treatment.<sup>12</sup>

Because no gold standard exists for physiotherapy in CF and it is unlikely that any one technique reigns supreme, it would seem appropriate to select a technique from the spectrum available that suits the individual's requirements.<sup>11</sup>

Bronchoalveolar lavage studies in infants with CF indicate the presence of infection and

Respiratory Unit,  
Great Ormond Street  
Hospital for Children  
NHS Trust, London  
WC1N 3JH, UK  
C Wallis  
A Prasad

Correspondence to:  
Dr Wallis.  
email: c.wallis@ich.ucl.ac.uk

inflammation within the airways at an early stage, even before clinical manifestations.<sup>13 14</sup> For this reason, prophylactic chest physiotherapy is often introduced at diagnosis, but this places a great burden on the family, and adherence to chest physiotherapy in CF is known to be poor.<sup>15</sup> The impact of early intervention on the natural history of the disease is unknown.

#### OTHER CAUSES OF BRONCHIECTASIS

There are a number of paediatric lung conditions that result in bronchiectatic changes and chronic sputum production. Examples include ciliary dyskinesia, postinfective destruction, and chronic aspiration. Although there are similar clinical features to CF, the underlying pathogenesis does not necessarily mean that the results of studies evaluating the role of physiotherapy in CF can automatically be extrapolated to this group.

A systematic review of randomised controlled trials estimating the magnitude of bronchial hygiene physical therapy (BHPT) interventions on patients with bronchiectasis (excluding CF) identified 10 randomised controlled trials and a total of 153 patients.<sup>16</sup> Studies with positive results involved a total of 67 patients of all ages but there was no paediatric subgroup analysis. There was no evidence that lung function was improved by BHPT. Beneficial effects were confined to sputum production and radio-aerosol clearance. Clinical outcomes considering morbidity and mortality are lacking and the routine application of BHPT to patients with chronic airways obstruction is not supported by available evidence.

#### Primary pneumonia

*"She was frothing at the nostrils and mouth corners, a death rattle on respiration and occasionally a sort of effort at clearing her throat. Several times each night the nurse compressed the chest and performed artificial respiration. The child begged to be left undisturbed, 'If you'll only let me alone,' she said. After a month the girl left the hospital quite well."*

Northrup WP. In: Paralysis of diaphragm and soft palate. *Transactions of the American Pediatric Society* 1904;16:245–8.

There have been two studies that looked at the role of physiotherapy in primary pneumonia although neither was confined specifically to the paediatric age group. In a randomised controlled trial, 54 patients with primary pneumonia and no underlying respiratory pathology were allocated to a treatment and non-treatment group. Chest physiotherapy did not hasten resolution for a number of outcome measures.<sup>17</sup> A Swedish study of 171 patients found no difference between placebo and physiotherapy treated groups for duration of hospital stay and improvement in lung function. Patients with pneumonia who had chest physiotherapy had a longer duration of fever than those not receiving treatment, an effect more pronounced in the younger patients.<sup>18</sup> This led to an editorial suggesting that chest physiotherapy may be harmful in some pa-

tients, especially those who do not produce excessive sputum.<sup>19</sup>

In general, it is accepted that application of manual techniques in patients with consolidation has no beneficial effect; however, the wider role that physiotherapy may play should be considered in terms of positioning to optimise ventilation and perfusion. Once the consolidatory phase begins to resolve, chest physiotherapy techniques might have some benefit in mobilising and clearing secretions, especially in the weak or uncooperative child.

#### Bronchiolitis

Chest physiotherapy is not uncommonly requested in children with acute viral bronchiolitis. A randomised study of twice daily chest physiotherapy in addition to standard supportive measures compared with a no physiotherapy control group found no significant difference for hospital stay, length of illness, or daily clinical score between the two groups.<sup>20</sup> This study was instigated when the authors found that chest physiotherapy for children with bronchiolitis had become the rule rather than the exception. A further trial has found no clinically discernible benefit of chest physiotherapy in bronchiolitis or impact on the course of the illness.<sup>21</sup>

#### Asthma

*"Massage is beneficial for asthmatic cases because the superficial circulation being improved, the congestion of the mucous membrane of the bronchial tubes is reduced, and probably there is a reflex action on the pulmonary branch of the pneumogastric nerve."*

Ellison MA. *A manual for students of massage*. London: Bailliere, Tindall and Cox, 1898.

Physiotherapy in acute, severe asthma has been studied in a group of 38 children aged 6–13 years.<sup>22</sup> The cohort was divided into a treatment group of 19 children who received physiotherapy within 24 hours after admission and 19 children who had placebo visits. Four physiotherapy sessions, preceded by nebulised salbutamol, were administered over two days. The two groups were similar in all other parameters. Lung function at the end of the study was similar in both groups and the authors concluded that chest physiotherapy did not improve lung function in children with acute severe asthma. In the presence of retained secretions, particularly in the ventilated asthmatic child, chest physiotherapy may be beneficial and expedite recovery. However, inappropriate treatment in the presence of bronchoconstriction might greatly exacerbate the situation.

The role of breathing exercises and posture in the management of children with more chronic asthma receives intermittent interest. There are psychological benefits in relaxation and controlled breathing exercises in these children.<sup>23</sup> Recently, the Buteyko method of controlled breathing in asthma has received positive media attention, but there has as yet been no published scientific evaluation.<sup>24</sup>

### Inhaled foreign body

*"Since the paper at the British Medical Association in 1902, the method of treating foreign bodies in the air passages has changed. No longer are children held upside down and slapped on the back as some cases are dying from spasm of the glottis. (Now) the trachea is opened and tickled with feathers to dislodge the foreign body. Be prepared to meet any emergency that may arise. That includes the presence of plenty of nurses."*

Silver HM. In: Abscess of the lung due to wire nail. *Transactions of the American Pediatric Society* 1908;20:209–12.

Chest physiotherapy aiming to remove an impacted object from the main bronchi is generally regarded as being of no value and as having potentially dangerous consequences.<sup>25</sup> The object could be mobilised further into a central airway causing complete occlusion or, if in the laryngeal region, it could cause a vagal response and devastating airway spasm. The treatment of choice is early bronchoscopic removal performed under controlled conditions.<sup>26</sup>

### Acute atelectasis

*"By causing the child to gag by putting an aseptic finger into the pharynx, you will be astonished to find that, in a child with interrupted breathing, who is getting worse and worse, with a number of moist rales in both sides of the lungs, the lungs clear up and regular breathing is established."*

Dr Saunders. In: Disturbances of respiration in the newborn. *Transactions of the American Pediatric Society* 1903;15:47.

There are a few studies that advocate physiotherapy to be an effective treatment in acute atelectasis, and positioning with vibration does perhaps aid recovery over hyperinflation and suctioning alone.<sup>27–28</sup> However, frequently these studies do not specifically consider the paediatric age group, where a child's inability to cooperate with deep inspiration and coughing may shift the need towards more formal physiotherapeutic assistance.

Acute lobar atelectasis as a result of mucous plugging is more commonly encountered in the intensive care setting and physiotherapy is often requested to assist in reinflation. Although much of the evidence for the beneficial effect of physiotherapy in children is anecdotal, there are reports of immediate radiological improvement following intervention.<sup>29</sup>

In the intubated patient, the endotracheal tube and mechanical ventilation can cause mucosal inflammation and increased secretions, but intubation and ventilation are not in themselves a prescription for physiotherapy. The rationale for treatment should be based on excessive secretions, atelectasis, or abnormal gas exchange. However, airway obstruction and lung collapse caused by retained bronchial secretions often complicate the clinical course and prolong the recovery phase and, therefore, can impact on long term outcome. In such situations, chest physiotherapy may facilitate reinflation of collapsed areas by the removal of obstructive secretions.

### The intubated neonate

Modern intensive care of very low birthweight infants often involves prolonged ventilatory support with all its commensurate problems. Chest physiotherapy has acquired a role in the management of these neonates. Some studies do suggest beneficial effects of chest physiotherapy in terms of secretion clearance and arterial oxygenation<sup>30–31</sup> but others, which look at specific treatment modalities, highlight potential deterioration in physiological parameters such as heart rate, respiratory rate, and oxygenation.<sup>32–33</sup> There are also reports of hypoxia,<sup>34</sup> rib fractures,<sup>35</sup> and periosteal reactions.<sup>36</sup> Reports of physiotherapy related encephaloclastic porencephaly<sup>37</sup> have been contradicted by a similar study in preterm infants that found no association between appropriately applied chest physiotherapy and abnormal neurological outcome.<sup>38</sup> The handling of a sick preterm infant should be minimal. Chest physiotherapy should only be applied if it is clearly indicated.

Studies use differing protocols and population groups and comparison of the results is difficult. Advances in neonatal ventilation, and the use of surfactant and antenatal steroids have changed the patient population since these early studies. The question remains as to how effective the use of chest physiotherapy is in neonatal intensive care.

Early uncomplicated neonatal respiratory distress syndrome related to surfactant deficiency does not require physiotherapy. Infrequent suction alone has been shown to be sufficient in maintaining the airway,<sup>39</sup> whereas routine chest physiotherapy in early respiratory distress syndrome has been associated with an increased incidence of intraventricular haemorrhage.<sup>40</sup>

### Postextubation

Chest physiotherapy is used widely to prevent postextubation complications. A systematic review of the effects of chest physiotherapy on neonates being extubated from mechanical ventilation for neonatal respiratory failure revealed only three randomised trials over the last two decades enrolling 138 babies.<sup>41</sup> The numbers were small and there was insufficient information to assess short and long term outcomes other than that there was no significant reduction in postextubation lobar collapse. Data on safety were insufficient and the conclusion of these authors echoes the response heard so often at the end of a systematic review of physiotherapy: the results of this review do not give a clear direction for the role of active chest physiotherapy for babies being extubated from mechanical ventilation in today's neonatal intensive care settings.

In a study of 63 neonates<sup>42</sup> who had been intubated for more than 24 hours, patients were randomised to receive treatment or no treatment immediately after extubation. In the 24 hour period after extubation the incidence of postextubation atelectasis was no different in the treated and untreated groups. These results are supported further by a recent retrospective radiographic study.<sup>43</sup>

### Chronic lung disease of prematurity

Physiotherapy may be recommended in chronic lung disease of prematurity not only to improve the neurological outcome, but also to maximise recovery and minimise the long term pulmonary sequelae. There are no studies of sufficient power or length to cater for the large number of confounding variables in analysis of the premature infant's long term recovery. Physiotherapy in these children is usually limited to acute exacerbations.<sup>44</sup>

### Physiotherapy and surgery

*"A very pleasant way of cleansing the thorax: . . . after incision of the chest and resection of the seventh rib, the child was seated in the bath. With every inspiration, the water would run into the opening and, with expiration, water would return laden with pus, which would sink to the bottom. Add warm water from time to time until the expiration gives out clear fluid. This method also recommends itself in treating such cases in private practice, owing to the ease with which it can be carried out by the child's parents, as well as by its inexpensiveness."*

Adams SS. In: Irrigation by submersion in the treatment of empyema. *Transactions of the American Pediatric Society 1898*;10:80-4.

Physiotherapy is often prescribed after abdominal or cardiac surgery in an attempt to counter the negative pathophysiological changes that occur in the postoperative period. Adult patients undergoing upper abdominal surgery show lung function changes after surgery that may persist for up to two weeks. A degree of atelectasis is almost invariable. Children and neonates are even more predisposed to postoperative respiratory failure because of poorly developed intercostal muscles and a compliant chest wall but less compliant lungs and poorly established collateral alveolar ventilation.<sup>45</sup>

Studies examining the use of physiotherapy as a prophylactic measure in the prevention of postoperative pulmonary complications are contradictory. There is considerable variability in patient groups, treatment modalities, and outcome measures that make meta-analysis impossible for the practitioner keen to tease out the truth. In some trials patients considered to be at risk are excluded from the study.<sup>46</sup> A recent randomised controlled trial of prophylactic physiotherapy introduced preoperatively in adults undergoing major abdominal surgery in a cohort of 174 treated patients and 192 controls reduced the incidence of postoperative complications in the treated group.<sup>47</sup> Patients with morbid obesity and those over 50 years who had smoked presented the highest risk for complications, a fact which highlights once again how trials undertaken in adult populations cannot automatically be extrapolated to paediatric patient groups. In one of the few studies in children, negative effects of routine chest physiotherapy after cardiac surgery are documented.<sup>48</sup>

Postoperative physiotherapy should never be "routine" but should be used judiciously. Specific physiotherapy techniques might have different effects on oxygen saturation and

haemodynamic stability in different age groups,<sup>49</sup> and careful assessment should ensure that the intervention is beneficial and effective rather than hazardous.

### Creating an evidence base for physiotherapy

*"The level of evidence on which treatment recommendations are made can be kept simple.*

NO CLEAR EVIDENCE: *opinions based on clinical experience, anecdotal studies or descriptive articles; conflicting evidence from studies or poorly designed studies, even if randomised controlled trials.*

SUGGESTIVE EVIDENCE: *evidence from cohort, case control, before-and-after studies; evidence from non-randomised experimental studies.*

FIRM EVIDENCE: *evidence from at least one properly designed randomised controlled trial with adequate sample selection, sample size, and appropriate controls; with double or single blinding and with clear outcomes."*

Feldman W, Rosser W, McGrath P. *Primary medical care of children and adolescents*. Oxford: Oxford University Press, 1987.

As we enter the new millennium, the randomised controlled trial reigns over other formats as most likely to stand up to scrutiny and provide the evidence we seek. In creating an evidence base for paediatric chest physiotherapy, however, there are problems in study design and protocols.

There is no placebo that blinds those involved in a trial of physiotherapy. There is no standard treatment against which others can be compared and the "art" of physiotherapy introduces a number of personal and uncontrollable factors. The longitudinal designs required for chronic pulmonary conditions are confounded by acute exacerbations, poor adherence, inconsistency of method, poorly defined treatment techniques, and the intrinsic and individual variations of the underlying disease. CF is the classic example where improvements or declines are inherently difficult to attribute to a single treatment factor alone.

Outcome measures need to be defined for the specific research question and to be both repeatable and reliable. Current methods of assessment are often imprecise: radiolabelled aerosols are affected by mucociliary clearance and deposition is affected by secretions and bronchial obstruction. Chest x ray changes may be too crude to pick up subtle differences. Oxygen saturation is an insensitive measure of pulmonary improvement while pulmonary function testing excludes a population of children who, for reasons of their disease or cooperation, are incapable of performing the techniques required.

Then there is the thorny issue of sputum collection. Because clearance of secretions is the goal of chest physiotherapy in many paediatric chest disorders, should the sputum produced not be the outcome measure of choice? Which is the better assessment, sputum production after a single treatment or over a 24 hour period? Do we measure volume or weight—accepting that variable amounts of sputum will be swallowed during the treatment

process or increased by salivary contribution. Does increased production of sputum equate to improvement?

There is a lack of robust scientific evidence to answer many of these questions and it is hoped that ongoing research will contribute to an expanding evidence base for physiotherapy intervention in paediatric respiratory disease. In the meantime, those involved in the management of paediatric respiratory disorders should avoid the unnecessary distress to both the child and family of useless treatment and the potentially serious consequences of inappropriate intervention.

- 1 Zach MS. Lung disease in cystic fibrosis—an updated concept. *Pediatr Pulmonol* 1990;8:188–202.
- 2 Partridge C, Pryor J, Webber BA. Characteristics of the forced expiration technique. *Physiotherapy* 1989;75:193–4.
- 3 Schoni MH. Autogenic drainage: a modern approach to physiotherapy in cystic fibrosis. *J R Soc Med* 1989;82:32–7.
- 4 Schibler A, Casaulta C, Kraemer R. Rationale of oscillatory breathing as chest physiotherapy performed by the flutter in patients with cystic fibrosis. *Pediatr Pulmonol* 1992;4:301.
- 5 Warwick WJ, Hansen LG. The long-term effect of high-frequency chest compression therapy on pulmonary complications of cystic fibrosis. *Pediatr Pulmonol* 1991;11:265–71.
- 6 Falk M, Kelstrup M, Andersen JB, et al. Improving the ketchup bottle method with positive expiratory pressure, PEP, in cystic fibrosis. *Eur J Respir Dis* 1984;65:423–32.
- 7 Oberwaldner B, Evans JC, Zach MS. Forced expirations against a variable resistance: a new chest physiotherapy method in cystic fibrosis. *Pediatr Pulmonol* 1986;2:358–67.
- 8 Kluff J, Beker L, Castagnino M, Gaiser J, Chaney H, Fink RJ. A comparison of bronchial drainage treatments in cystic fibrosis. *Pediatr Pulmonol* 1996;22:271–4.
- 9 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;50:165–9.
- 10 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. *J Pediatr* 1997;131:570–4.
- 11 Prasad SA, Main E. Finding evidence to support airway clearance techniques in cystic fibrosis. *Disabil Rehabil* 1998;20:235–46.
- 12 Thomas J, Cook DJ, Brooks D. Chest physical therapy management of patients with cystic fibrosis. A meta-analysis. *Am J Respir Crit Care Med* 1995;151:846–50.
- 13 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;310:1571–2.
- 14 Khan TZ, Wagener JS, Bost T, Martinez J, Accurso FJ, Riches DW. Early pulmonary inflammation in infants with cystic fibrosis. *Am J Respir Crit Care Med* 1995;151:1075–82.
- 15 Geiss SK, Hobbs SA, Hammersley-Maercklein G, Kramer JC, Henley M. Psychosocial factors related to perceived compliance with cystic fibrosis treatment. *J Clin Psychol* 1992;48:99–103.
- 16 Jones AP, Rowe BH. Bronchopulmonary hygiene physical therapy in chronic obstructive pulmonary disease and bronchiectasis (Cochrane review). In: *The Cochrane Library*, Issue 3, Oxford: Update Software, 1998.
- 17 Graham WG, Bradley DA. Efficacy of chest physiotherapy and intermittent positive-pressure breathing in the resolution of pneumonia. *N Engl J Med* 1978;299:624–7.
- 18 Britton S, Bejstedt M, Vedin L. Chest physiotherapy in primary pneumonia. *BMJ* 1985;290:1703–4.
- 19 Selsby DS. Chest physiotherapy. *BMJ* 1989;298:541–2.
- 20 Webb MS, Martin JA, Cartlidge PH, Ng YK, Wright NA. Chest physiotherapy in acute bronchiolitis. *Arch Dis Child* 1985;60:1078–9.
- 21 Dhouieb E, Dick K, Edmunds AT, Marshall TT. Evaluation of chest physiotherapy in patients with bronchiolitis. *Physiotherapy*. [In press.]
- 22 Asher MI, Douglas C, Airy M, Andrews D, Trenholme A. Effects of chest physical therapy on lung function in children recovering from acute severe asthma. *Pediatr Pulmonol* 1990;9:146–51.
- 23 Webber BA. Evaluation and inflation in respiratory care. *Physiotherapy* 1991;77:801–4.
- 24 Berlowitz D, Denchy L, Johns DP, Bish RM, Walters EH. The Buteyko asthma breathing technique [letter]. *Med J Aust* 1995;162:53.
- 25 Phelan PD, Olinsky A, Robertson CF. Pulmonary complications of inhalation. In: *Respiratory illness in children*, 4th ed. Oxford: Blackwell Scientific Publications, 1994:264–6.
- 26 Ahmed AA. Bronchoscopic extraction of aspirated foreign bodies in children in Harare Central Hospital, Harare, Zimbabwe. *Cent Afr J Med* 1994;40:183–6.
- 27 Marini JJ, Pierson DJ, Hudson LD. Acute lobar atelectasis: a prospective comparison of fiberoptic bronchoscopy and respiratory therapy. *Am Rev Respir Dis* 1979;119:971–8.
- 28 Stiller K, Geake T, Taylor J, Grant R, Hall B. Acute lobar atelectasis. A comparison of two chest physiotherapy regimens. *Chest* 1990;98:1336–40.
- 29 Mellins RB. Pulmonary physiotherapy in the pediatric age group. *Am Rev Respir Dis* 1974;110:137–42.
- 30 Etches PC, Scott B. Chest physiotherapy in the newborn: effect on secretions removed. *Pediatrics* 1978;62:713–5.
- 31 Finer NN, Boyd J. Chest physiotherapy in the neonate: a controlled study. *Pediatrics* 1978;61:282–5.
- 32 Tudehope DI, Bagley C. Techniques of physiotherapy in intubated babies with the respiratory distress syndrome. *Aust Paediatr J* 1980;16:226–8.
- 33 Curran CL, Kachoyanos MK. The effects on neonates of two methods of chest physical therapy. *MGN: Am J Matern Child Nurs* 1979;4:309–13.
- 34 Fox WW, Schwartz JG, Shaffer TH. Pulmonary physiotherapy in neonates: physiologic changes and respiratory management. *J Pediatr* 1978;92:977–81.
- 35 Purohit DM, Caldwell C, Levkoff AH. Multiple rib fractures due to physiotherapy in a neonate with hyaline membrane disease [letter]. *Am J Dis Child* 1975;129:1103–4.
- 36 Wood BP. Infant ribs: generalized periosteal reaction resulting from vibrator chest physiotherapy. *Radiology* 1987;162:811–12.
- 37 Harding JE, Miles FK, Becroft DM, Allen BC, Knight DB. Chest physiotherapy may be associated with brain damage in extremely premature infants. *J Pediatr* 1998;132:440–4.
- 38 Beeby PJ, Henderson-Smart DJ, Lacey JL, Rieger I. Short- and long-term neurological outcomes following neonatal chest physiotherapy. *J Paediatr Child Health* 1998;34:60–2.
- 39 Wilson G, Hughes G, Rennie J, Morley C. Evaluation of two endotracheal suction regimes in babies ventilated for respiratory distress syndrome. *Early Hum Dev* 1991;25:87–90.
- 40 Raval D, Yeh TF, Mora A, Cuevas D, Pyati S, Pildes RS. Chest physiotherapy in preterm infants with RDS in the first 24 hours of life. *J Perinatol* 1987;7:301–4.
- 41 Flenady VJ, Gray PH. Chest physiotherapy for babies being extubated from mechanical ventilation (Cochrane review). In: *The Cochrane Library*, Issue 3, Oxford: Update Software, 1998.
- 42 Al-Alaiyan S, Dyer D, Khan B. Chest physiotherapy and post-extubation atelectasis in infants. *Pediatr Pulmonol* 1996;21:227–30.
- 43 Bloomfield FH, Teele RL, Voss M, Knight DB, Harding JE. The role of neonatal chest physiotherapy in preventing postextubation atelectasis. *J Pediatr* 1998;133:269–71.
- 44 Unwin JF. Long-term sequelae of bronchopulmonary dysplasia: a review of the literature. *Physiotherapy* 1993;79:633–6.
- 45 Hatch D, Sumner E, Hellman J. *The surgical neonate: anaesthesia and intensive care*. London: Edward Arnold, 1995.
- 46 Nichols PJR, Howell B. Routine pre- and post-operative physiotherapy. *Rheumatology and Physical Medicine* 1971;10:321–36.
- 47 Fagevik OM, Hahn I, Nordgren S, Lonroth H, Lundholm K. Randomized controlled trial of prophylactic chest physiotherapy in major abdominal surgery. *Br J Surg* 1997;84:1535–8.
- 48 Reines HD, Sade RM, Bradford BF, Marshall J. Chest physiotherapy fails to prevent postoperative atelectasis in children after cardiac surgery. *Ann Surg* 1982;195:451–5.
- 49 Hussey J, Hayward L, Andrews M, Macrae D, Elliot M. Chest physiotherapy following paediatric cardiac surgery: the influence of mode of treatment on oxygen saturation and haemodynamic stability. *Physiotherapy Theory and Practice* 1996;12:77–85.