Physiotherapy 119 (2023) 17–25

Chest physiotherapy for mechanically ventilated children: a survey of current UK practice

Emma Shkurka[a,b,*], Jo Wray[c], Mark J. Peters[b,d], Harriet Shannon[b]

[a] *Physiotherapy Department, Great Ormond Street Hospital for Children NHS Foundation Trust, London, UK*
[b] *Infection, Immunity & Inflammation Department, UCL Great Ormond Street Institute of Child Health, London, UK*
[c] *Centre for Outcomes and Experience Research in Children's Health, Illness and Disability, Great Ormond Street Hospital for Children NHS Foundation Trust, London, UK*
[d] *Paediatric Intensive Care Unit, Great Ormond Street Hospital for Children NHS Foundation Trust, London, UK*

Abstract

Objectives Chest physiotherapy is a treatment option for mechanically ventilated children. However, there is a lack of consensus regarding its value and informal discussions suggest variation in practice. This study describes chest physiotherapy practices for mechanically ventilated children in the UK and explores clinical decision making related to its delivery.
Design Cross-sectional study, using an anonymous, electronic survey.
Participants Qualified physiotherapists working in UK NHS paediatric intensive care units (PICUs).
Results The response rate was 61% (72/118), this included physiotherapists from 26/27 (96%) PICUs. All participants reported using manual hyperinflations and position changes 'always' or 'often'. Variation in practice was evident for some techniques, including Metaneb® and percussion. DNase (99%, 71/72) and hypertonic saline (90%, 65/72) were the most frequently used mucoactives: 91% (59/65) of physiotherapists reported only nebulising hypertonic saline and 69% (49/71) use both nebulised and instilled DNase. Use and delivery of N-acetylcysteine was inconsistent (nebulised only 55%, 26/47; instilled only 15%, 7/47; both 30%, 14/47). Chest physiotherapy was most commonly delivered with a nurse (67%, 48/72). Clinical decision making processes were comparable between physiotherapists and encompassed three main elements: individual patient assessment, involvement of the multidisciplinary team, and risk versus benefit analysis.
Conclusions A range of chest physiotherapy treatments and adjuncts were used with ventilated children. Variation was apparent and may be due to individual preferences of those training staff or local policies. Pragmatic, interventional studies are required to determine best practice. Further exploration is necessary to understand the variation in practice and intricacies of decision making.

Key words: Infant/child; Respiration artificial; Physical therapy modalities; Lung; Respiratory therapy

Introduction

Paediatric intensive care units (PICUs) support the complex needs of critically ill children. Although life-saving, therapies provided in the PICU, including intubation and mechanical ventilation, can impair airway clearance. This increases the risk of secretion retention, airway occlusion, atelectasis and infection [1,2]. Underlying respiratory pathology in ventilated children can also lead to mucus hypersecretion. Chest physiotherapy is a recognised treatment option for mechanically ventilated children [3,4]. The main aims are to facilitate the removal of tracheobronchial secretions and recruit areas of atelectasis, improving mucociliary clearance and ventilation [2,4].

There is a lack of consensus regarding the value of chest physiotherapy in ventilated children. The UK Quality Standards for the Care of Critically Ill or Injured Children (2021) require PICUs to have access to physiotherapy 24 h a day [5]. European recommendations from the Paediatric Mechanical Ventilation Consensus Conference state that

* Correspondence to: Physiotherapy Department, Great Ormond Street Hospital for Children NHS Foundation Trust, Great Ormond Street, London WC1N 3JH, UK.
E-mail address: emma.shkurka@gosh.nhs.uk (E. Shkurka).

https://doi.org/10.1016/j.physio.2022.11.004

chest physiotherapy for airway clearance cannot be considered a standard of care [6]. The evidence to support chest physiotherapy in invasively ventilated children was reported as inconclusive in a recently published systematic review [7]. The thirteen studies included in the review were of mixed quality, investigated a range of physiotherapy treatments, and demonstrated poor generalisability.

Canadian chest physiotherapy practice in paediatric intensive care has been studied in a single centre, retrospective trial [8]. One hundred and eleven children received chest physiotherapy over one year. Manual hyperinflations (MHI) with expiratory chest wall vibrations (CWV) were the most frequently used techniques (96%). Other treatments included percussion, bed mobility and assisted cough. Chest physiotherapy practice and delivery has been studied more comprehensively in adult intensive care. Surveys of practice have been completed in Australia, New Zealand, Brazil and Zimbabwe [9–13]. Commonly used treatments included MHI, positioning, CWV and percussion. However, the authors reported variability in physiotherapists' clinical reasoning and subsequent practice [9, 12, 13]. Informal clinical discussions between PICUs suggest similar variations, although this has not been captured formally.

Prior to embarking on multi-centre, interventional trials a greater understanding of current chest physiotherapy practice is essential. At present there are no published studies examining chest physiotherapy practice and delivery within UK PICUs. Therefore, the aim of this study was to describe chest physiotherapy practice for invasively ventilated children in the UK and explore clinical decision making related to its provision and delivery.

Methods

Study design

A cross-sectional observational study was conducted using a bespoke anonymous electronic survey. This was performed and reported in line with the Checklist for Reporting Results of Internet E-Surveys [14].

Sample and recruitment

All 27 UK NHS PICUs were invited to participate [5]. The lead physiotherapist on each unit was contacted directly via email. They were invited to participate and asked to disseminate the study invitation and survey link to appropriate physiotherapists based on their unit. The inclusion criteria were full or part time, static or rotational qualified physiotherapists working in a PICU. Physiotherapists who worked in paediatric intensive care only as part of on-call/emergency shifts were excluded. The lead physiotherapists were also asked to inform the researcher, via email, of the number of physiotherapists the invitation was sent to, allowing calculation of an approximate response rate. Following centre recruitment and dissemination of the invitation, the survey link remained active for eight weeks. Two reminder emails were sent.

Survey development

A bespoke survey was developed following a focus group with five respiratory physiotherapists. The survey included 21 items across four domains: demographics, chest physiotherapy techniques, decisions regarding delivery of treatment and instability/adverse events (Supplementary material I). Dichotomous and multiple choice closed questions were used, including Likert scales. Survey items related to clinical decision making were open-ended and used free text responses. A pilot was conducted with seven paediatric physiotherapists who did not work in PICU, and minor adjustments were made to improve clarity and layout.

Ethical considerations

The study was approved by the Health Research Authority (IRAS 278215) and University College London research ethics committee (ID 16837/001). NHS ethics approval was not required as the study only involved NHS staff. Physiotherapists were provided with a participant information sheet and consent was implied if a completed survey was submitted.

Data management and statistical analysis

Data were collected via SmartSurvey™ and analysed using SPSSv27 statistical software (IBM Corp, Chicago, Illinois, USA). Frequency counts and percentages were used for dichotomous data. Post-hoc subgroup analysis, involving years of experience, was completed using Fisher's exact test. Statistical significance was set at $P < 0.05$. Quantitative data were displayed using Visual Individual Likert Data (VILD) charts. Free text responses were analysed using inductive content analysis. A second coder was used for face validity.

Results

Survey response

Twenty-six of the 27 (96%) UK PICUs were recruited. Based on lead physiotherapist feedback the survey link was disseminated to approximately 118 physiotherapists. Seventy-two completed the survey, providing a response rate of 61% (72/118). Data were collected between 29th July 2020 and 8th February 2021. Only one question was not completed by all the participants (Question 6). This question related to extended-scope skills. As 'none of the

above' was not an answer option, it is possible that those who did not complete the question had no extended-scope skills to report.

Demographics

Physiotherapists from all regions of the UK participated. Due to the anonymous nature of the survey geographical data were collected in broad geographical regions only. The proportion of participants from each region closely matched the geographical spread of PICUs in the UK (Supplementary material II). All participants reported providing chest physiotherapy assessment and treatment to mechanically ventilated children. All but one physiotherapist reported that their PICU had access to an overnight and weekend service. Physiotherapists ranged in years of experience from < 1 year to > than 20 years, with the highest proportion (23/72, 32%) reporting 1–5 years of PICU experience.

Delivery of chest physiotherapy

The most common approach to delivering chest physiotherapy was with the bedside nurse (48/72, 67%). Treatment was provided independently by 26% (19/72) of physiotherapists and 7% (5/72) involved another physiotherapist. No physiotherapists with < 1 year of experience reported treating independently.

Chest physiotherapy treatments

A variety of treatments were used with intubated and ventilated children (Fig. 1). MHI and position changes were used 'always' or 'often' by all physiotherapists. Most physiotherapists used CWV (64/72, 89%) and endotracheal tube (ETT) saline instillation (65/72, 90%) 'always' or 'often'. Ventilator hyperinflations were 'never' or 'rarely' used by 72% of physiotherapists (52/72). Other treatments consistently used 'never' or 'rarely' included intrapulmonary percussive ventilation (IPV) (67/72, 93%), Metaneb® (63/72, 88%), high frequency chest wall oscillation (HFCWO) (60/72, 83%) and physiotherapy assisted bronchoscopy (57/72, 79%). There was greater variation in the use of other treatments including chest wall decompression, percussion, directed saline lavage and manual insufflation/exsufflation (MI:E) (Fig. 1), with responses ranging from 'often' to 'never'. There was a trend of more frequent use of physiotherapy assisted bronchoscopy by therapists with greater PICU experience ($p = 0.025$) (Table 1). Directed saline lavage was used more frequently by physiotherapists with 1–5 years of experience and those with > 10 years of experience ($p = 0.039$) (Table 2). There were no statistically significant relationships between years of experience and the remaining treatments (Supplementary material III).

Use of mucoactive agents

All physiotherapists reported using at least one mucoactive agent. Three percent hypertonic saline, 7% hypertonic saline and DNase were the most frequently used (Fig. 2). Three percent hypertonic saline was used 'always' or 'often' by 57% (41/72) of physiotherapists, 7% hypertonic saline by 44% (32/72) and DNase by 25% (18/72). NAC was used less frequently by physiotherapists with 15 to < 20 years of experience when compared to the other groups; 64% (7/11) reported 'never' using NAC ($p = 0.047$). Seven percent hypertonic saline was used less frequently by physiotherapists with < 1 year of experience and those with 15 to < 20 years of experience, compared to the other groups ($p = 0.014$). No differences were observed on subgroup analysis with DNase, 3% or 6% hypertonic saline (Supplementary material IV).

Nebulisation was the only delivery method used by 96% (26/27) of physiotherapists for 6% hypertonic saline, 92% (60/65) for 7% hypertonic saline, and 91% (59/65) for 3% hypertonic saline. Most physiotherapists (49/71, 69%) used DNase in both nebulised and instilled forms. The method of delivery of NAC was inconsistent: nebulised only 26/47, 55%; instilled only 7/47, 15%; both 14/47, 30%.

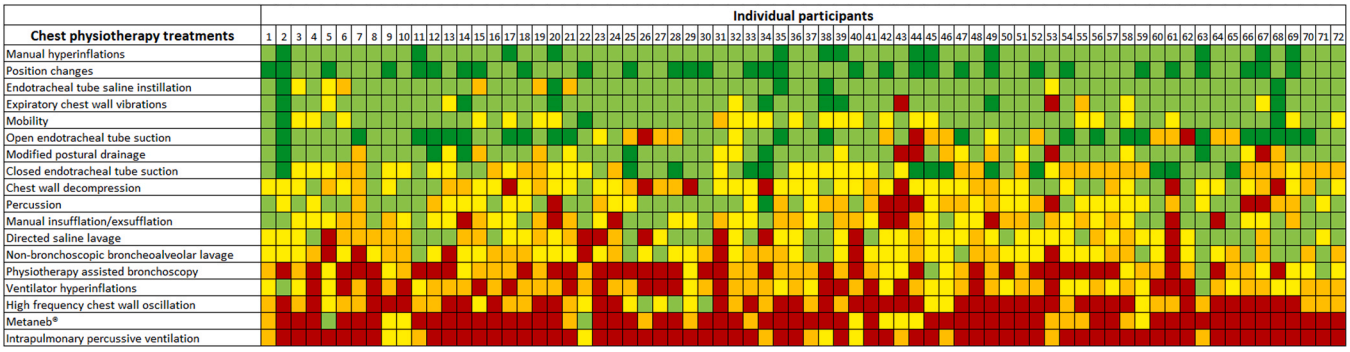

Fig. 1. – Visual individual Likert data (VILD) chart of frequency of use of chest physiotherapy treatments in intubated and ventilated patients. Key: dark green - always, light green - often, yellow - sometimes, orange - rarely, red - never (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article).

Table 1
Frequency of use of physiotherapy assisted bronchoscopy by years of PICU experience (*total > 100 due to rounding).

Years of PICU experience	Frequency of use of Bronchoscopy % (n)*				
	Never	Rarely	Sometimes	Often	Always
< 1 year (n = 4)	100 (4)	0	0	0	0
1 to < 5 years (n = 23)	39 (9)	52 (12)	9 (2)	0	0
5 to < 10 years (n = 19)	58 (11)	21 (4)	21 (4)	0	0
10 to < 15 years (n = 8)	63 (5)	13 (1)	25 (2)	0	0
15 to < 20 years (n = 11)	18 (2)	36 (4)	36 (4)	9 (1)	0
> 20 years (n = 7)	43 (3)	29 (2)	0	29 (2)	0
Total	n = 34	n = 23	n = 12	n = 3	n = 0

Table 2
Frequency of use of directed saline lavage by years of PICU experience (*total > 100 due to rounding).

Years of PICU experience	Frequency of use of directed saline lavage % (n)*				
	Never	Rarely	Sometimes	Often	Always
< 1 year (n = 4)	75 (3)	0	25 (1)	0	0
1 to < 5 years (n = 23)	4 (1)	17 (4)	39 (9)	39 (9)	0
5 to < 10 years (n = 19)	11 (2)	42 (8)	37 (7)	11 (2)	0
10 to < 15 years (n = 8)	13 (1)	13 (1)	13 (1)	63 (5)	0
15 to < 20 years (n = 11)	9 (1)	9 (1)	36 (4)	46 (5)	0
> 20 years (n = 7)	0	14 (1)	57 (4)	29 (2)	0
Total	n = 8	n = 15	n = 26	n = 23	n = 0

Outcomes

All physiotherapists reported using heart rate and peripheral oxygen saturations (SpO_2) to monitor patient stability during chest physiotherapy (Fig. 3). Blood pressure was used by 99% (71/72) and end tidal carbon dioxide ($EtCO_2$) by 97% (70/72) of physiotherapists. Additional variables reported were ventilator parameters, extracorporeal membrane oxygenation (ECMO) flows and observation of the patient including colour, chest movement and work of breathing. All physiotherapists reported using SpO_2 and auscultation to determine the effectiveness of treatment. Ventilation parameters, $EtCO_2$, palpation and secretion yield were also frequently reported outcome measures (≥ 97% of participants, 70/72).

Extended-scope skills

Thirty-eight (53%) physiotherapists responded to this question. It was presumed the 34 (47%) who skipped it had nil to report. Eighteen physiotherapists (47%) reported using 1 extended-scope skill, with the remaining 20 (53%) reporting 2 or more. Thirty-seven physiotherapists (97%) reported completing ventilator weaning and 17 (45%) physiotherapy led extubation (Fig. 4). All physiotherapists with < 1 year of experience (n = 4) reported no extended-scope skills. There were no other relationships with years of experience.

Clinical decision making

Two overarching themes were derived from the analysis of the free-text responses for chest physiotherapy referral processes: first line processes and second line/back-up pathways (Table 3). Fifty-six physiotherapists (78%) provided descriptions of this combined approach. First line processes were physiotherapy led and included handovers and multidisciplinary team (MDT) ward rounds. Daily screening and automatic/routine referrals were also mentioned frequently. These approaches are illustrated in the following quote:

"Attending ward round twice a week, open MDT discussions. Daily screening of online notes and imaging" (P16)

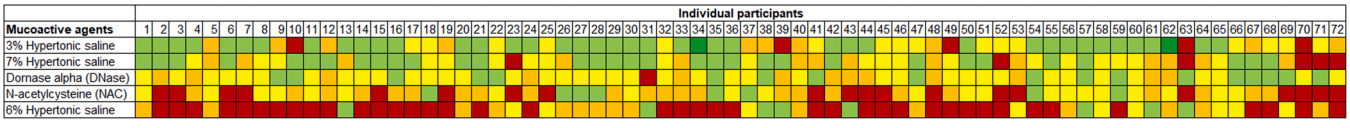

Fig. 2. – Visual individual Likert data (VILD) chart of frequency of use of mucoactives in intubated and ventilated patients. Key: dark green - always, light green - often, yellow - sometimes, orange - rarely, red - never (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article).

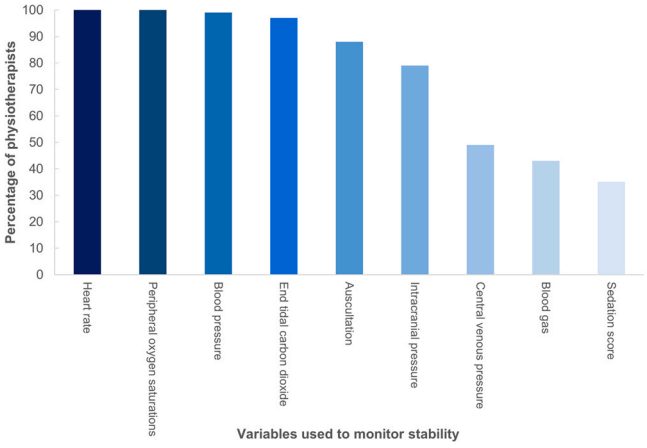

Fig. 3. – Variables used by physiotherapists to monitor the stability of patients during chest physiotherapy.

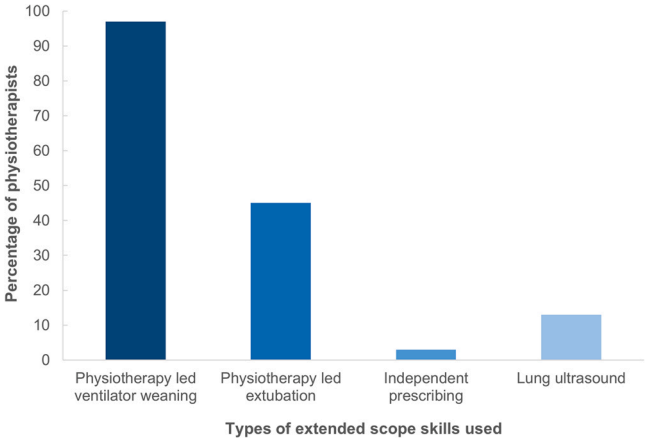

Fig. 4. - The types of extended scope skills used by physiotherapists (n = 38).

Second line pathways were predominantly direct referrals from the MDT via paging systems/electronic notes/face-to-face.

The most frequently reported factors that influenced how physiotherapists made decisions about frequency of treatment were individual patient assessment using clinical reasoning, and severity of symptoms (Table 4). Thirty-eight physiotherapists provided specific symptoms or indicators for treatment, the most common being increased secretion yield or viscosity (36/38, 95%) and chest x-ray (CXR) changes (14/38, 37%). Discussion and liaison with the MDT was stated as contributing to decision making. The child's response to physiotherapy treatment was also described as a factor, which included both tolerance and effectiveness of treatment; *"How did they tolerate treatment? If poorly then likely will not do it multiple times" (P54).*

Five themes were identified from physiotherapists' responses when asked to outline any patient groups that did not receive chest physiotherapy whilst mechanically ventilated. Physiotherapists stated that, for some patients, there was *"no acute need"* for treatment. Examples included non-respiratory diagnoses, end of life patients and those with a short period of ventilation. The second theme was that treatments were based on individual assessment, but that no specific groups would be avoided, as illustrated below:

"No blanket rule, but would be based on morning screening/handover and physiotherapists clinical reasoning" (P6)

"No specific groups – patients very much assessed on an individual basis" (P32)

Specific contra-indications to chest physiotherapy emerged as the third theme, the most frequently reported being acute haemorrhage, unstable neurology and pneumothorax. The final themes were based around a perception of the patient being too unstable for physiotherapy and the need for a risk versus benefit assessment, as described in the following quotes:

"Children who are unstable. Benefits of any physio intervention must always outweigh the risk" (P5)

"Only when the risk of doing physiotherapy outweighs the risk of not doing it. It's a balancing act of all the systems" (P12)

Discussion

To our knowledge, this is the first study to explore chest physiotherapy practice in mechanically ventilated children within the UK. All responding physiotherapists reported providing chest physiotherapy to mechanically ventilated children. MHI, position changes, CWV and ETT saline instillation were reported as the most frequently used treatments. Mucoactive agents, as an adjunct to physiotherapy, were used by all participants, with DNase and, 3% and 7% hypertonic saline being the most frequently used. There was variation in the personnel involved in delivering treatment and the use of some treatment components, together with the type and delivery of mucoactives. Clinical decision making processes were comparable between physiotherapists and encompassed three main elements; individual patient assessment, involvement of the MDT, and risk versus benefit analysis.

The physiotherapists surveyed in this study reported using a variety of chest physiotherapy treatments. These findings support chest physiotherapy as a multicomponent treatment, in which techniques are used in combination. The most frequently used treatments reported in this study were position changes, ETT saline instillation, MHI and CWV. These findings are in line with a retrospective study of chest physiotherapy in a Canadian PICU, where MHI with CWV (96%) and bed mobility (20%) were the most frequently used techniques [8]. Similar practice has been

Table 3
Content analysis of referral processes.

Pathway	Strategies	Number of physiotherapists
First line	Handover/MDT ward round	43
	Daily screening	21
	Automatic/routine	14
	Blanket referral	10
Secondary	Direct referral from MDT	58
	Urgent on call referral	15

Table 4
Content analysis of factors which influence the frequency of physiotherapy assessment and treatment.

Factors	Number of physiotherapists
Individual assessment/clinical reasoning	55
Severity of symptoms/clinical presentation	44
Effectiveness/impact of treatment	36
Tolerance of treatment	24
General stability	16
Multidisciplinary team discussion	13
Ability of nursing staff to manage secretions	11
Directed by medical/nursing team	5
Related to timing of other procedures	5
Unit practice/protocol	3
Dependent on staffing levels	2

described in adult intensive care [9, 10, 12]. Contrasting practice has been reported in Indian PICUs. Percussion was the most frequently used chest physiotherapy treatment reported in 25 PICUs in Punjab, India, with 90% (76/84) of respondents using this [15]. CWV were used by 68% (57/84) and MHI was not used. This study included both mechanically ventilated and self-ventilating children which may provide rationale for the differences observed in treatment popularity.

Despite the apparent popularity of MHI, CWV, saline instillation and position changes the evidence to support these treatments is limited. The results of a recent systematic review investigating chest physiotherapy in mechanically ventilated children were inconclusive, with statistically, but not clinically significant improvements reported in expired tidal volume and respiratory compliance following treatment with MHI, CWV and postural drainage [7]. Significant changes to ventilation distribution in children treated with MHI, manual techniques and suction, compared to suction alone have been demonstrated with electrical impedance tomography (EIT) [16]. These changes may be indicative of atelectatic alveoli recruitment, although further studies are required to validate EIT as an outcome measure. In experimental studies, MHI and CWV have been shown to increase peak expiratory flow resulting in a favourable airflow bias, promoting central movement of secretions and airway clearance [17–19]. There is ongoing debate regarding the efficacy of saline instillation in mechanically ventilated patients. Historically it has been used under the assumption that saline facilitates the removal of secretions by lubricating the suction catheter, thinning and dislodging secretions, and eliciting a cough [20]. However, the ability of mucus and water to mix, even after vigorous shaking, has been questioned [21]. The use of ETT saline instillation with suctioning on PICU has been associated with a transient decrease in oxygen saturations [22]. Although the authors also concluded that saline may have a positive effect in children with obstructive mucus. Despite the American Association for Respiratory Care guidelines for artificial airway suctioning recommending that the use of normal saline should be avoided, it continues to be popular [23].

Mucoactive agents were used frequently by the physiotherapists in our study. In a UK survey of mucoactive use for ventilated asthmatic children, 63% (55/87) of PICU consultants reported using DNase and 54% (46/85) hypertonic saline [24]. DNase was used by 86% (6/7) of PICUs in the Netherlands [25]. This national survey focused exclusively on DNase practice, and reported it was most frequently prescribed for bronchiolitis, neuromuscular disease, and pneumonia. Mucoactive agents are also becoming increasingly popular in adult intensive care. Within the UK, 83% (106/128) of adult intensive care units use mucoactives [26]. Mode of delivery varied between agents in our study. DNase was delivered via nebulisation and instillation, whereas hypertonic saline was predominantly nebulised. This is in line with practice described in published literature [24,25].

The reported mechanisms of action of mucoactives include improved mucus rheology, restoration of the periciliar layer, anti-inflammatory properties and cough induction [27]. However, at present there is limited evidence of their effectiveness in mechanically ventilated children. 3% hypertonic saline has been reported as safe in a range of mechanically ventilated neonatal and paediatric patients, however the clinical effects are mixed [28–30]. Improvements in mean atelectasis scores, oxygenation and length of ventilation have been reported with the use of DNase in children who have undergone cardiac surgery [31–33]. The role of mucoactives has been well established in other, non-ventilated paediatric populations, including cystic fibrosis,

bronchiectasis, and more recently mild-moderate bronchiolitis [34,35]. PICU physiotherapists decisions to use mucoactives may be based on published literature in these populations, anecdotal evidence and personal experience. NAC was used less frequently in our study. In the UK survey of ventilated asthmatics only 19% of consultants reported using NAC [26]. The apparent lack of popularity may be due to minimal published research. Studies are limited to single case-studies involving neonatal patients. Given the extensive use of mucoactives on PICUs further studies into their effectiveness are required.

The results of our survey demonstrated variation in practice, which included the choice of treatment components, type and delivery method of mucoactives, and personnel involved in the delivery of chest physiotherapy. National variation in chest physiotherapy practice on adult ICU has been described in the UK [36]. International variation is also apparent from the adult literature; MHI is used less frequently in Zimbabwe compared to Australia, New Zealand and Brazil [9–12]. Regional differences may be due to individual preferences of those training staff, local policies/protocols, or historical practice. Although not explored in this study regional differences may have accounted for some of the variation observed. Length of experience influenced treatment choice in Brazilian adult ICUs; percussion and postural drainage were chosen more often by physiotherapists with greater experience [9]. Physiotherapy assisted bronchoscopy, a complex procedure, was used more frequently by physiotherapists with greater PICU experience in our study. However, there were no other relationships between years of PICU experience and treatment or mucoactive selection, which is in line with adult data from Australia [14]. Variation in practice observed in adult ICUs in Zimbabwe has been attributed to differences in patient diagnoses [11]. This level of data was not available in our study and warrants further investigation.

The physiotherapists in this study described the use of several physiological variables, together with observation and palpation of the patient, to monitor stability and determine treatment effectiveness. The physiological outcomes, which included ventilation and cardiovascular parameters, are standard monitoring for ventilated children and used routinely by health professionals on PICU. Auscultation was a popular tool in this study. Auscultation is an important part of respiratory examination, used to assess airflow through the tracheal-bronchial tree. It is inexpensive, non-invasive, and safe. Recently the value of auscultation has been debated, in the context of new bedside assessment tools, including lung ultrasound and EIT. These, point of care, lung imaging modalities are becoming increasingly popular in intensive care and physiotherapy [17,37]. Advantages over conventional tools include improved sensitivity and specificity, together with higher diagnostic accuracy [38]. Hansell et al. (2021) reported that lung ultrasound has the potential to more accurately monitor change associated with chest physiotherapy treatments [38]. Lung ultrasound was mentioned infrequently in this study, possibly indicating it is not yet established in PICU physiotherapy practice.

This is the first study to explore physiotherapist decision making on paediatric intensive care. The results demonstrated consistency in the reported approaches used by physiotherapists. Clinical decision making was described as patient focussed through individual assessment and clinical reasoning, collaborative with the MDT, and weighing up the risk of treatment compared to its benefit. Physiotherapists' use of airway clearance and mucoactive agents in adult intensive care has also been described as patient centred and targeted to individual need [36]. Similar findings were reported by Smith et al. (2008), who investigated the characteristics of physiotherapy decision making in acute respiratory care [39]. Decisions were based around the nature of patients' problems, physiotherapeutic intervention, and evaluation of effectiveness. The authors also suggested that clinical decision making is a social and collaborative process. In adult intensive care, decision making and provision of chest physiotherapy has been related to work-load and staffing levels [12,36], however this was not a common theme in our study. This may be related to the differing demands of paediatric and adult patients. In general adults are larger and heavier, requiring multiple individuals to re-position and/or complete interventions. The individual patient approach described by the physiotherapists in our study supports previous literature suggesting that practice has moved away from routine or prophylactic chest physiotherapy on PICUs [3,40]. Secretion yield/viscosity and CXR changes were the most commonly reported clinical indications for treatment. These findings are in line with those of McCord et al. (2013), who reported the most common reasons for referral on PICU were pathological changes on CXR and secretion retention [8]. Although this survey provides initial data, more in-depth investigation is required to provide greater understanding of what constitutes best practice and support the development of training resources.

Whilst this study provides a detailed exploration of chest physiotherapy practice in UK PICUs the results should be interpreted in the context of several limitations. As with any survey, there is a risk of self-report bias, and responses may not reflect what actually happens in the clinical setting. Participants may have responded with socially desirable answers. However, the anonymous design was chosen to encourage accuracy and honesty. The response rate was lower than anticipated, particularly when compared to a physiotherapy survey in adult intensive care, which reported a 72% response rate [12]. However, surveys involving professionals on PICU appear to have lower response rates (46–65%) [15, 24, 25]. The lower response rate in this study was partially attributed to data collection during a pandemic; PICUs within the UK were re-purposed and health professionals re-deployed. Staff within the NHS

were under significant stress and may not have had time or capacity to take part. Selection bias also requires consideration due to the unknown characteristics and practise of non-responders. Furthermore, there is a risk that individual institutions may be over-represented. Given the anonymous nature of the survey specific unit details were not collected. Despite these limitations, the sample included physiotherapists with the full range of years of PICU experience and representation from all geographical regions, therefore we believe the results to be generalisable to current UK practice.

Conclusion

A range of chest physiotherapy treatments and adjuncts were used by physiotherapists for mechanically ventilated children in UK PICUs. Variation was apparent and may be due to individual preferences of those training staff or local policies. Physiotherapists reported using individual patient assessment and clinical reasoning to make decisions regarding provision and delivery of chest physiotherapy. Involvement of the MDT was also reported as having a key role. Pragmatic, interventional studies are required to determine best practice with regards to treatment types and the use of mucoactives. Further qualitative exploration is required to provide a greater understanding of the variation in practice and the intricacies of clinical decision making.

Ethical Approval

The study was approved by the Health Research Authority (IRAS 278215) and University College London research ethics committee (ID 16837/001).

Funding: This study was funded by the National Institute for Health Research (NIHR) [ICA-CDRF-2018-ST2–018] and was supported by the National Institute for Health Research Great Ormond Street Hospital Biomedical Research Centre. The views expressed are those of the author(s) and not necessarily those of the NIHR or the Department of Health and Social Care.

Conflict of Interest

None declared.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.physio.2022.11.004.

References

[1] Morrow BM, Argent A. A comprehensive review of pediatric endotracheal suctioning: Effects, indications, and clinical practice. Pediatr Crit Care Med 2008;9(5):465–77.
[2] Pryor JA, Prasad SA. Physiotherapy for Respiratory and Cardiac Problems. 4th ed. United Kingdom: Churchill Livingstone Elsevier; 2008.
[3] Morrow BM. Chest physiotherapy in the pediatric intensive care unit. J Pediatr Intensive Care 2015;4(4):174–81.
[4] Pathmanathan N, Beaumont N, Gratrix A. Respiratory physiotherapy in the critical care unit. Contin Educ Anaesth Crit Care Pain 2015;15(1):20–5.
[5] Paediatric Critical Care Society. Quality Standards for the Care of Critically Ill or Injured Children. Paediatr Crit Care Soc 2021. October 2021.
[6] Kneyber MCJ, de Luca D, Calderini E, Jarreau P-H, Javouhey E, Lopez-Herce J, *et al.* Recommendations for mechanical ventilation of critically ill children from the Paediatric Mechanical Ventilation Consensus Conference (PEMVECC). Intensive Care Med 2017;43(12):1764–80.
[7] Shkurka E, Wray J, Peters M, Shannon H. Chest physiotherapy for mechanically ventilated children: a systematic review. J Pediatr Intensive Care 2021.
[8] McCord J, Krull N, Kraiker J, Ryan R, Duczeminski E, Hassall A, *et al.* Cardiopulmonary physical therapy practice in the paediatric intensive care unit. Physiother Can 2013;65(4):374–7.
[9] Matilde INE, Eid RAC, Nunes AF, Ambrozin ARP, Moura RH, Carnieli-Cazati D, *et al.* Bronchial hygiene techniques in patients on mechanical ventilation: what are used and why? Einstein 2018;16(1):eAO3856-eAO.
[10] Ntoumenopoulos G, Hammond N, Watts NR, Thompson K, Hanlon G, Paratz JD, *et al.* Secretion clearance strategies in Australian and New Zealand Intensive Care Units. Aust Crit Care 2018;31(4):191–6.
[11] Tadyanemhandu C, Manie S. Profile of patients and physiotherapy patterns in intensive care units in public hospitals in Zimbabwe: a descriptive cross-sectional study. BMC Anesthesiol 2015;15:136.
[12] Van der Lee L, Hill A-M, Patman S. A survey of clinicians regarding respiratory physiotherapy intervention for intubated and mechanically ventilated patients with community-acquired pneumonia. What is current practice in Australian ICUs? J Eval Clin Pract 2017;23(4):812–20.
[13] Van der Lee L, Hill A-M, Patman S. Expert consensus for respiratory physiotherapy management of mechanically ventilated adults with community-acquired pneumonia: a Delphi study. J Eval Clin Pract 2019;25(2):230–43.
[14] Eysenbach G. Improving the quality of Web surveys: the Checklist for Reporting Results of Internet E-Surveys (CHERRIES). J Med Internet Res 2004;6(3):e34.
[15] Kumar A, Shergill N, Jairaman. Chest physiotherapy techniques used in neonatal and paediatric intensive care units in Punjab. Exerc Fit Health Alliance 2014;10(1):11–5.
[16] McAlinden B, Kuys S, Schibler A, Hough JL. Chest physiotherapy improves regional lung volume in ventilated children. Crit Care 2020;24(1):440.
[17] Gregson RK, Shannon H, Stocks J, Cole TJ, Peters MJ, Main E. The unique contribution of manual chest compression-vibrations to airflow during physiotherapy in sedated, fully ventilated children. Pediatr Crit Care Med 2012;13(2):e97–102.
[18] Gregson RK, Stocks J, Petley GW, Shannon H, Warner JO, Jagannathan R, *et al.* Simultaneous measurement of force and respiratory profiles during chest physiotherapy in ventilated children. Physiol Meas 2007;28(9):1017–28.
[19] Shannon H, Stiger R, Gregson RK, Stocks J, Main E. Effect of chest wall vibration timing on peak expiratory flow and inspiratory

pressure in a mechanically ventilated lung model. Physiotherapy 2010;96(4):344–9.
[20] Blackwood B. Normal saline instillation with endotracheal suctioning: primum non nocere (first do no harm). J Adv Nurs 1999;29:928–34.
[21] Demers RR, Saklad M. Minimizing the harmful effects of mechanical aspiration. Heart Lung 1973;2:542–5.
[22] Schults J, Mitchell ML, Cooke M, Schibler A. Efficacy and safety of normal saline instillation and paediatric endotracheal suction: An integrative review. Aust Crit Care: Off J Confed Aust Crit Care Nurses 2018;31(1):3–9.
[23] Blakeman TC, Scott JB, Yoder MA, Capellari E, Strickland SL. AARC clinical practice guidelines: artificial airway suctioning. Respir Care 2022;67:258–71.
[24] Snoek A, Brierley J. Mucolytics for intubated asthmatic children: a national survey of United Kingdom paediatric intensive care consultants. Crit Care Res Pract 2015:1–5.
[25] Den Hollander B, Linssen RSN, Cortjens B, Van Etten-Jamaludin FS, Van Woensel JBM, *et al.* Use of dornase alfa in the paediatric intensive care unit: current literature and a national cross-sectional survey. Eur J Hosp Pharm 2020;0:1–6. https://doi.org/10.1136/ejhpharm-2020-002507
[26] Borthwick M, McAuley D, Warburton J, Anand R, Bradley J, Connolly B, *et al.* Mucoactive agent use in adult UK Critical Care Units: a survey of health care professionals' perception, pharmacists' description of practice, and point prevalence of mucoactive use in invasively mechanically ventilated patients. PeerJ 2020;8:e8828.
[27] Balsamo R, Lanata L, Egan CG. Mucoactive drugs. Eur Respir Rev 2010;19(116):127.
[28] Hsieh C-W, Chen C, Su H-C, Chen K-H. Exploring the efficacy of using hypertonic saline for nebulizing treatment in children with bronchiolitis: a meta-analysis of randomized controlled trials. BMC Pediatr 2020;20(1):434.
[29] Shein SL, Gallagher JT, Deakins KM, Weinert DM. Prophylactic use of nebulized hypertonic saline in mechanically ventilated children: a randomized blinded pilot study. Respir Care 2016;61(5):586.
[30] Stobbelaar K, Kool M, de Kruijf D, Van Hoorenbeeck K, Jorens P, De Dooy J, *et al.* Nebulised hypertonic saline in children with bronchiolitis admitted to the paediatric intensive care unit: a retrospective study. J Paediatr Child Health 2019;55(9):1125–32.
[31] Ozturk E, Tanidir IC, Haydin S, Onan IS, Odemis E, Bakir I. The use of dornase alpha for post-operative pulmonary atelectasis after congenital heart surgery. Cardiol Young 2014;24(5):807–12.
[32] Prodhan P, Greenberg B, Bhutta AT, Hyde C, Vankatesan A, Imamura M, *et al.* Recombinant human deoxyribonuclease improves atelectasis in mechanically ventilated children with cardiac disease. Congenit Heart Disease 2009;4(3):166–73.
[33] Riethmueller J, Borth-Bruhns T, Kumpf M, Vonthein R, Wiskirchen J, Stern M, *et al.* Recombinant human deoxyribonuclease shortens ventilation time in young, mechanically ventilated children. Pediatr Pulmonol 2006;41(1):61–6.34.
[34] Rosenfeld M, Ratjen F, Brumback L, Daniel S, Rowbotham R, McNamara S, *et al.* Inhaled hypertonic saline in infants and children younger than 6 years with cystic fibrosis: the ISIS randomized controlled trial. JAMA 2012;307(21):2269–77.
[35] Zhang L, Mendoza-Sassi RA, Wainwright C, Klassen TP. Nebulised hypertonic saline solution for acute bronchiolitis in infants. Cochrane Database Syst Rev 2017(12).
[36] Connolly B, Barclay M, Blackwood B, Bradley J, Anand R, Borthwick M, *et al.* Airway clearance techniques and use of mucoactive agents for adult critically ill patients with acute respiratory failure: a qualitative study exploring UK physiotherapy practice. Physiotherapy 2020;108:78–87.
[37] Hayward SA, Janssen J. Use of thoracic ultrasound by physiotherapists: a scoping review of the literature. Physiotherapy 2018;104:367–75.
[38] Hansell L, Milross M, Delany A, Tian DH, Ntoumenopoulos G. Lung ultrasound has greater accuracy than conventional respiratory assessment tools for the diagnosis of pleural effusion, lung consolidation and collapse: a systematic review. J Physiother 2021;67:41–8.
[39] Smith M, Higgs J, Ellis E. Characteristics and processes of physiotherapy clinical decision making: a study of acute care cardiorespiratory physiotherapy. Physiother Res Int 2008;13(4):209–22.
[40] Hawkins E, Jones A. What is the role of the physiotherapist in paediatric intensive care units? A systematic review of the evidence for respiratory and rehabilitation interventions for mechanically ventilated patients. Physiotherapy 2015;101(4):303–9.