Airway clearance techniques for the intubated adult: a scoping review

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Abstract

Objective

The aim of this scoping review was to understand the extent and type of evidence available in relation to airway clearance techniques in the intubated adult.

Introduction

This review was commissioned by the Association of Chartered Physiotherapists in Respiratory Care (ACPRC) special interest group as a method of summarising the available evidence on this topic on behalf of its members. Airway clearance in the intubated adult is a key objective of respiratory physiotherapists and although evidence-based guidelines exist in this area, there is no recent summary regarding the extent of the literature which could inform future research and clinical practice.

Inclusion criteria

Studies which investigated adults who were intubated either via an endo-tracheal or tracheostomy tube met the criteria. All study designs, including reviews, case reports and animal studies, which reported any physiotherapy-related airway clearance techniques were included.

Methods

The following databases were searched: SCOPUS, PubMed, PEDro, CINAHL Plus, and Clinical Trials Registry. The search was completed in December 2021 and limited to full text papers published since 2011. Following the key word search strategy, each title and abstract was screened for relevance to the scoping review aim and the study design was identified. *Population*, *intervention*, *comparator* and *outcome* (PICO) data extraction was completed for all included papers in order to identify themes. The number and type of evidence retrieved, as well as key themes and outcomes were summarised.

Results

The scoping review identified 138 suitable papers for inclusion. Of these, 11 were systematic reviews and 39 were randomised clinical trials, representing a moderately large evidence-base on this topic. Also included were other experimental, observational and qualitative studies, narrative reviews and animal and bench studies. Key interventions were identified including multi-modal chest physiotherapy, hyperinflation and manual chest compression techniques. Reported outcome measures were mainly short-term, such as sputum yield and oxygenation, whilst longer-term outcome measures such as ICU length of stay and ventilator-associated pneumonia (VAP) rates were reported less frequently. Outcome measures related to physiological stability were also reported by some studies.

Findings of the review were that airway clearance techniques for the intubated adult appear to be safe. There is a moderate body of evidence regarding their efficacy for short-term outcomes such as sputum yield, oxygenation and respiratory mechanics. There is limited evidence regarding their efficacy for longer-term outcomes.

Conclusion

This scoping review summarises the extent of available evidence regarding airway clearance for intubated adults. Future research should focus on the effects of airway clearance techniques on longer-term outcome measures such as VAP rates and extubation outcome.

Introduction

The ACPRC editorial board is comprised of respiratory physiotherapy clinicians and academics who have volunteered through their ACPRC membership to be part of the editorial board. The purpose of the board is to lead scoping, commissioning, co-ordination and delivery of all new ACPRC guidance documents and resources, in order to facilitate knowledge sharing and drive improvements in the quality of care for respiratory patients.

The editorial board discussed potential areas for investigation which had been suggested by its membership and agreed that the area of airway clearance for the intubated adult should be prioritised. The lead author Gabriella Cork, as a member of the editorial board, was nominated to lead the scoping review and other ACPRC members who were practising respiratory physiotherapist clinicians volunteered to assist with the process.

Airway clearance for the intubated adult is an important responsibility for respiratory physiotherapists in the intensive care unit (ICU) (1) and involves the mobilisation and subsequent removal of respiratory secretions via the endotracheal or tracheostomy tube. Intubation and the associated mechanical ventilation, prolonged recumbency and sedation result in reduced cough efficacy, reduced mucociliary transport and atelectasis which can in turn lead to retained secretions and ventilator-associated pneumonia (2, 3, 4, 5). Physiotherapeutic techniques to assist with the removal of sputum from the intubated patient such as manual chest compression, hyperinflation and positioning are frequently used by physiotherapists (6, 7). However, evidence investigating the efficacy of such techniques has been deemed overall of poor quality with conflicting findings (8).

Recent Faculty of Intensive Care Medicine (FICM) guidelines recommend 'targeted airway clearance interventions' for invasively ventilated patients but do not stipulate which airway clearance interventions should be utilised (9). Furthermore, the same publication recommends that individual physiotherapy services should develop their own evidence-based guidelines for the use of airway clearance techniques. A major purpose of this scoping review was to determine whether there is sufficient evidence available on this topic to inform collaborative clinical guidelines.

A preliminary search of SCOPUS and the Cochrane Database of Systematic Reviews was conducted and whilst recent reviews in this area exist, they have focused on individual techniques such as manual therapy (10) or hyperinflation (11, 12), on specific populations such as those with community-acquired pneumonia (13) and traumatic brain injury (14), or on specific outcomes such as ventilation-associated pneumonia (VAP) rates (15). One systematic review (8) did have a wider focus and included a variety of physiotherapeutic techniques and outcomes relevant to airway clearance, however a number of new experimental studies have subsequently been published. These have not yet been captured by guidelines, recommendations or systematic review and may further contribute to the knowledge base in this topic.

The aim of this scoping review is to understand the extent and type of evidence in relation to airway clearance in the intubated adult in order to inform future recommendations for respiratory physiotherapy clinicians and researchers.

Review question

What is the extent of the current evidence-base in relation to airway clearance in the intubated adult?

Eligibility criteria

Participants

Adults who were intubated either via endotracheal or tracheostomy tube at the time of the investigation. Paediatric studies were excluded.

Concept

Airway clearance techniques that are performed by physiotherapists as summarised by Berry et al (16). Additional airway clearance techniques that are more commonly performed by medical staff such as bronchoscopy or that are pharmacological in nature were excluded. Techniques such as automated lateral bed rotation, humidification or endotracheal suctioning alone were excluded as these were deemed to be primarily routine, nurse-delivered interventions.

Context

Airway clearance techniques for the intubated adult are usually performed in the ICU, however studies were not excluded if they investigated intubated adults in other clinical settings such as weaning units or post-op recovery areas. This scoping review was planned and initial searches conducted prior to the global COVID-19 pandemic, therefore studies relating to the treatment of COVID-19 were excluded as they were deemed by the co-authors to be beyond the initial remit and purpose of the review.

Types of sources

This scoping review considered both experimental and quasi-experimental study designs including randomised controlled clinical trials, non-randomised controlled trials and before and after studies. In addition, analytical observational studies including prospective and retrospective cohort studies, case-control studies and analytical cross-sectional studies were considered for inclusion. This review also included descriptive observational study designs including case series, individual case reports and descriptive cross-sectional studies as well as animal and bench studies. Qualitative studies on this topic were additionally summarised alongside systematic reviews and meta-analyses that met the inclusion criteria.

Opinion papers (including editorials) as well as conference abstracts were excluded.

Methods

The scoping review was conducted in accordance with the JBI methodology for scoping reviews (17).

Search strategy

An initial limited search of SCOPUS was undertaken to identify articles on the topic. The text words contained in the titles and abstracts of relevant articles, the index terms used to describe the articles, and a collaborative, iterative process by the co-authors were used to develop a full search strategy (see Appendix 1 for full SCOPUS search strategy). The search strategy, including all identified keywords and index terms, was adapted for each of the included databases. The reference lists of all review papers were subsequently screened for additional studies.

Studies published in any language where a full English version was available were included. Studies published from 2011 onwards were included as the most comprehensive systematic review was published in 2013, and the vast majority of its 85 included papers were published pre-2011 (8).

The databases searched were SCOPUS, PubMed, CINAHL Plus, and PEDro. Google Scholar search engine was additionally employed using the same search terms, limited to the initial 500 papers due to default sort by relevance. The Clinical Trials Registry was also searched for unpublished studies that were completed within the previous three years which might reasonably be in the process of being published at the time of the review. The final search was completed in December 2021.

Source of evidence selection

Following the search, titles and abstracts were screened by co-authors (Clare Wade, Alison Gordon, Anna Vaughan-France, Amelia Palmer, Katy Walker and Una Jones) for assessment against the inclusion criteria. Potentially relevant sources were retrieved in full and uploaded into EndNote X9, 2018 (Clarivate Analytics, P.A., U.S.A.) and duplicates removed. The full text of selected citations was assessed in detail against the inclusion criteria by the lead author (Gabriella Cork) and cross-checked independently by Clare Wade. Reasons for the exclusion of evidence following full text review were recorded and reported (Figure 1).

Data extraction and synthesis

Data regarding study design, population, intervention, comparator and outcome (PICO) was extracted from papers included in the scoping review by the co-authors using a data extraction tool developed by Una Jones. The data extracted included key findings relevant to the review question. Themes were identified during the data extraction process and the papers grouped both by type of evidence and sub-themes within the overall airway clearance topic. For papers which included more than one type of airway clearance, the intervention was classified as 'multi-modal chest physiotherapy'. Key outcome measures were also identified. Due to the breadth of the scoping review, quality assessment of the experimental papers was not undertaken beyond classifying them according to their study design.

Results

The scoping review retrieved 138 relevant papers (see Figure 1). Of these, 11 were systematic reviews (summarised in Appendix 1) and 39 were randomised clinical trials (summarised in Appendix 2), see Figure 2 for full break-down of papers by evidence-type and Appendices 3–8 for summaries of all other included papers.

The most common reported intervention was multi-modal chest physiotherapy with 45 publications exploring this topic. Common airway clearance techniques such as hyperinflation and manual chest compressions were also extensively studied. Figure 3 gives a full break-down of the papers included in the scoping review according to their theme.

The key interventions, outcome measures and findings from comparative studies included in this scoping review are summarised in Table 1. The most commonly reported outcome measures were sputum yield and oxygenation.

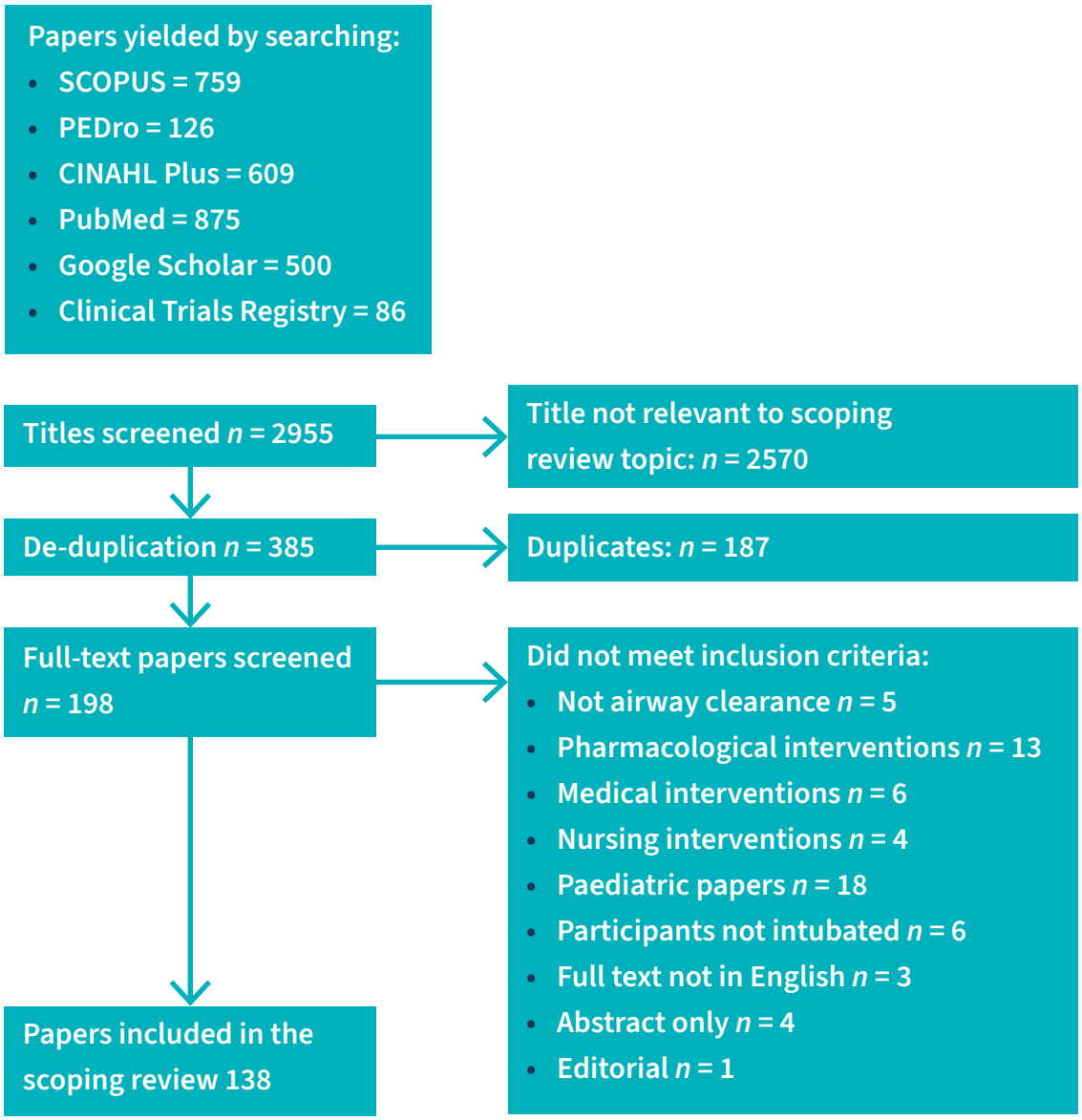

Figure 1: PRISMA flow chart for the scoping review process.

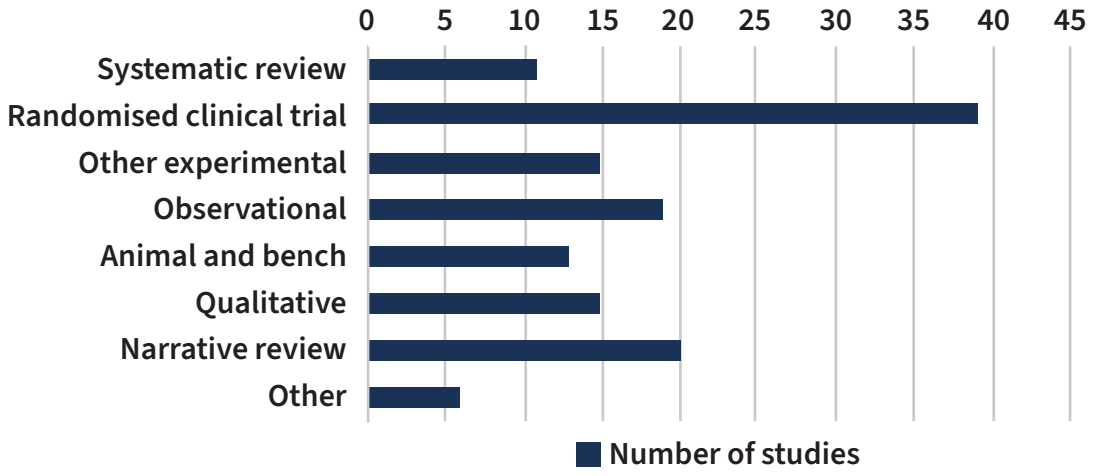

Figure 2: Summary of included sources according to evidence type.

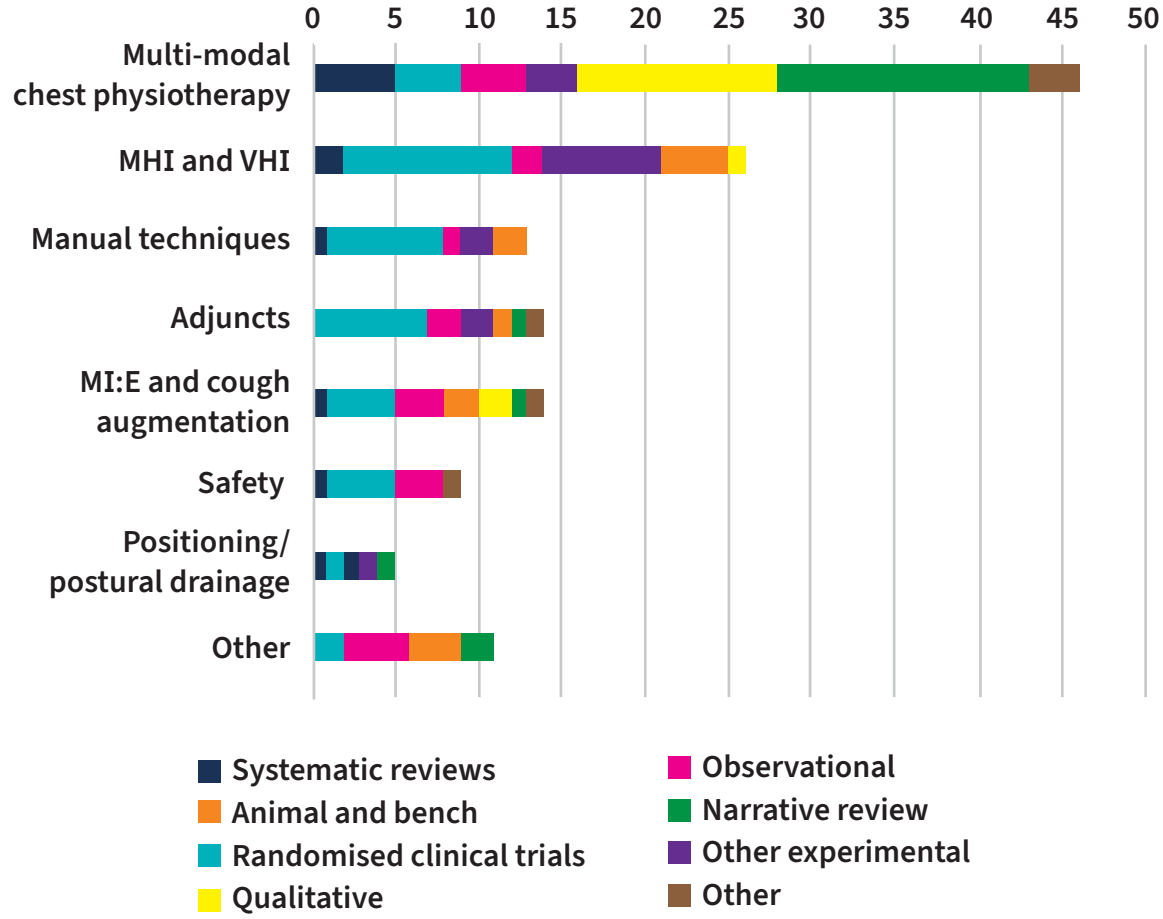

Figure 3: Summary of included sources according to theme and evidence type.

MHI = manual hyperinflation; VHI = ventilator hyperinflation; MI:E = mechanical in-exsufflation.

Table 1: Summary of key interventions and outcome measures.

		Multi-modal	MHI/VHI	Manual techniques	Cough augmentation	Positioning	Adjuncts
Short-term outcome measures	Sputum yield	*Systematic review:* van der Lee, 2020+ *RCT:* Naue, 2014+	*Systematic review:* Anderson, 2015= Paulus, 2012+ *RCT:* Dennis, 2012= Jacob, 2020+ Naue, 2011= Naue, 2019+ *Experimental:* Bhoir, 2017= El-Deen, 2013+ Ibrahim, 2018+	*Systematic review:* Borges, 2017= *RCT:* Genc, 2011= Guimaraes, 2014+ Yousefnia-Darzi, 2016+ *Laboratory:* Ouchi, 2020+ *Experimental:* Suh, 2011=	*RCT:* Coutinho, 2018= de Camilis, 2018+ Martinez-Alejos, 2021+	*RCT:* Shetty, 2020+	*RCT:* Chicayban, 2011+ Jones, 2013+ Kluayhom-thong, 2019+ *Experimental:* Kuyrukluyildiz, 2016+
	Oxygenation	*Systematic review:* Andrews, 2013+ *RCT:* Mohamed, 2017+ *Observational:* Meawad, 2018 Moreira, 2015= Ntoumenopoulos, 2014- *Experimental:* Hariedy, 2015+	*Systematic review:* Anderson, 2015= Paulus, 2012+ *RCT:* Malekzadeh, 2016+ Mohamed, 2017+ *Observational:* Frank, 2015+ *Experimental:* Bhoir, 2017= El-Deen, 2013+ Ibrahim, 2018+ Raafat, 2011+ Waqas, 2014+	*Systematic review:* Borges, 2017= *RCT:* Genc, 2011= Kohan, 2014+ *Observational:* Via, 2012+ *Experimental:* Ashtankar, 2019+	None	*Systematic review:* Hewitt, 2016+ *Experimental:* Guner, 2015=	*Observational:* Lee, 2011= *Experimental:* Kuyrukluyildiz, 2016+
	Respiratory mechanics	*Systematic review:* Andrews, 2013+ Stiller, 2013+ Van der Lee, 2020+ *RCT:* Naue, 2014+ Observational: Moreira, 2015+	*Systematic review:* Anderson, 2015= Paulus, 2012+ *RCT:* Linnane, 2019= Paulus, 2011+ Ribeiro, 2019 *Experimental:* Bhoir, 2017=	*Systematic review:* Borges, 2017= *Observational:* Via, 2012+ *Experimental:* Ashtankar, 2019+ Suh, 2011+	*RCT:* de Camilis, 2018+ Martinez-Alejos, 2021+	None	*RCT:* Chicayban, 2011+ Chuang, 2017+ *Experimental:* Longhini, 2020+
	Peak expiratory flow/expiratory flow bias	None	*RCT:* Ribeiro, 2019 *Laboratory:* Bennett, 2015 Chapman, 2019 Li Bassi, 2019= Thomas, 2015 *Experimental:* Paulus, 2014	*RCT:* Amaral, 2019+ Oliveira, 2019+ *Laboratory:* Marti, 2013+	*Laboratory:* Guerin, 2011 Volpe, 2018	*Laboratory:* Li Bassi, 2014+	*RCT:* Chicayban, 2011+ *Laboratory:* Fernandez-Restrepo, 2017

Longer-term outcome measures	Ventilator-acquired pneumonia rates	*Systematic review:* Pouzuelo-Carrascosa, 2018= Stiller, 2013= Wang, 2019= *RCT:* Mohamed, 2017+ Pattanshetty, 2011+ *Observational:* Kubo, 2021+	None	*RCT:* El-Hamid, 2017+	*Observational:* Kuroiwa, 2021+	*Laboratory:* Li Bassi, 2014+	*RCT:* Spapen, 2015+ *Experimental:* Kuyrukluyildiz, 2016+
	Mortality	*Systematic review:* Pouzuelo-Carrascosa, 2018+	None	None	None	None	None
	ICU length of stay/ duration of mechanical ventilation	*Systematic review:* Pouzuelo-Carrascosa, 2018= Stiller, 2013= Van der Lee, 2020= *RCT:* Berti, 2012+ Pattanshetty, 2011- Mohamed, 2017+ *Experimental:* Castro, 2013+ Wang, 2018=	None	None	*Systematic review:* Rose, 2017+	None	*RCT:* Chen, 2016+ Clinkscale, 2012= *Observational:* Lee, 2011=
	Extubation/ weaning success	*Experimental:* Wang, 2018+	None	None	*Systematic review:* Rose, 2017+ *RCT:* Goncalves, 2012+ *Observational:* Bach, 2015	None	None
Physio-logical stability	Haemodynamic observations	*RCT:* Blattner, 2017- *Observational:* Neto, 2013= Jiandani, 2018= Ntoumenopoulos, 2014=	*RCT:* Ribeiro, 2019	*RCT:* Boussari, 2014- Tomar, 2019-	*Systematic review:* Rose, 2017=	*Systematic review:* Hewitt, 2016= *RCT:* Hongratta, 2014- *Experimental:* Guner, 2015-	None
	Neurological observations	*Systematic review:* Ferreira, 2013- *Observational:* Neto, 2013=	None	*RCT:* Tomar, 2019-	None	None	None

= Denotes no significant difference between intervention and control/comparison.

+ Denotes significant finding in favour of the intervention compared with control/comparison.

- Denotes significant finding in favour of the control/comparison compared with the intervention.

RCT = randomised clinical trial; MHI = manual hyperinflation; VHI = ventilator hyperinflation.

A summary of the non-experimental research included in this scoping review is provided in Table 2.

Table 2: Summary of non-experimental research.

Method	Author	Country	Aims	Study population
Survey	Hayes 2011	Australia and New Zealand	VHI practice	Physiotherapists
	Bhat 2014	India	Chest physiotherapy in neuro ICU	Physiotherapists (44.3% response)
	Lottering 2016	South Africa	Physiotherapy practice in South African ICUs	Physiotherapists (33.8% response)
	Rose 2016	Canada	Cough augmentation techniques in critically ill	Physiotherapists
	Grammatopoulo 2017	Greece	Physiotherapy services provided in public ICUs	ICU directors and ICU physiotherapists (68.7% response)
	Matilde 2017	Brazil	Bronchial hygiene techniques in ventilated patients	Physical therapists – on call or intensive care specialists
	Newstead 2017	Australia	Critical care nurses' attitudes to traditional chest physiotherapy	Critical care nurses (response rate 12%)
	Rose 2018	Canada and U.K.	Use of airway clearance strategies in NMD and SCI requiring NIV or IMV	Respiratory clinicians across U.K. ($n = 63$) and Canada ($n = 92$)
	Stilma 2021	Netherlands	Airway care interventions for mechanically ventilated patients	ICU clinical representative (92% nurses) (85% response rate)
Delphi	Skinner 2016	Australia and New Zealand	Minimum standards of clinical practice for physiotherapists working in critical care	Experts – clinical and academic physiotherapists >5 years' experience
	Twose 2019	U.K.	Minimum standards of clinical practice for physiotherapists working in critical care	Experts – clinical and academic physiotherapists >3 years experience
	van der Lee 2019	International	Respiratory physiotherapy management of ventilated adults with community acquired pneumonia	Experts – clinical and academic physiotherapy experts

Qualitative	Connolly 2020	U.K.	Airway clearance techniques and use of mucoactive agents for critically ill patients with respiratory failure	Physiotherapists >2 years' experience
	van der Lee 2020	Australia	Clinical validation of expert consensus statements for respiratory physiotherapy management of mechanically ventilated patients	Physiotherapists, nurses, consultant intensivists

ICU = intensive care unit; VHI = ventilator hyperinflation; IMV = invasive mechanical ventilation; NMD = neuromuscular disease; SCI = spinal cord injury; NIV = non-invasive ventilation.

Discussion

The papers retrieved by this deliberately wide-ranging scoping review were diverse and as well as clinical efficacy papers, included assessment of the requirements for airway clearance techniques (ACTs), physiological effects of ACTs, opinions of caregivers, service delivery and clinical recommendations.

Non-experimental research

Clinician opinion regarding airway clearance techniques using surveys of current practice has been the subject of a number of recent studies (18, 19, 20, 21, 22, 23, 24). These surveys have highlighted that a number of varying airway clearance and cough augmentation techniques are used by critical care clinicians. Studies reported heterogeneity of intensity and combination of ACTs in addition to variation in clinical practice. Rationale for commencing airway clearance techniques is similar across studies, including to aid in sputum clearance and promotion of improved alveolar recruitment and ventilation. Some studies highlight that lack of knowledge, training, and expertise may contribute to reduced adoption of techniques such as mechanical in-exsufflation (22) and ventilator hyperinflation (23). Such studies recognise the lack of clinical guidance in this area.

Qualitative studies with physiotherapists and wider critical care clinicians highlight the importance of teamwork, clinical reasoning, clinical experience and communication as key in the selection and effective implementation of airway clearance interventions for mechanically ventilated adults (6, 25).

A recent focus of non-experimental research has been the production of clinical guidelines using a Delphi technique to achieve expert consensus, specifically to identify core clinical competencies for practitioners implementing airway clearance techniques (1, 26) and best practice for the treatment of community-acquired pneumonia (21). Expert consensus panels recognise that physiotherapy competence in airway clearance interventions such as hyperinflation techniques, manual chest wall techniques, positioning, normal saline

instillation and suction are a minimum standard of practice for physiotherapists working in ICU in their respective countries (1, 26). This scoping review did not retrieve any recent clinical guidelines to aid in the selection, implementation or evaluation of airway clearance techniques for non-specific intubated adults.

Experimental research: short-term outcomes

Papers focusing on clinical efficacy investigated interventions that enhanced inspiratory volume and/or expiratory flow. The effects of such airway clearance techniques were primarily reported on short-term outcomes such as oxygenation, sputum yield, respiratory mechanics (for example, dynamic compliance) and peak expiratory flow (PEF; either absolute PEF or peak inspiratory-expiratory flow (PIF:PEF) ratio). Although sputum yield is the most direct outcome measure for the efficacy of airway clearance techniques, oxygenation and respiratory mechanics are reported frequently. Techniques which appear to enhance sputum yield include adjuncts such as high-frequency chest wall oscillation (HFCWO) and oscillatory positive expiratory pressure (OPEP) devices (27, 28, 29, 30), head down positioning (31), and multi-modal chest physiotherapy (13, 32). The evidence for the effect of hyperinflation, manual techniques and cough augmentation on sputum yield is mixed, with contradictory findings. Several studies have reported no difference in effect between manual hyperinflation and ventilator hyperinflation regarding sputum yield, including a systematic review (11).

The most effective interventions to improve oxygenation in the short-term appear to be manual and ventilator hyperinflation with multiple studies reporting statistically significant if not necessarily clinically significant findings in favour of this intervention (12, 33, 34, 35, 36, 37, 38, 39). Improvements in respiratory mechanics such as static and dynamic lung compliance were reported with multi-modal chest physiotherapy by multiple systematic reviews (8, 13, 40). Several experimental studies reported a similar effect with airway clearance adjuncts (27, 41, 42) which seems to be an emerging area of research that warrants further attention.

Animal studies have investigated the effect of airway clearance techniques on PEF, particularly to determine whether the threshold for mucous movement can be achieved by head down positioning and manual techniques (43, 44). A number of clinical studies have also explored this outcome measure with adjuncts (27) and manual techniques (45, 46) being shown to improve PEF.

Cardiovascular and neurological stability have been investigated in a number of studies and whilst some statistically significant deteriorations have been reported during various airway clearance techniques, authors concluded that these were transient and non-clinically significant. This suggests that ACTs are safe for the intubated patient (47, 48).

Experimental research: longer-term outcomes

Longer-term outcome measures such as mortality, ICU length of stay, ventilator-acquired pneumonia (VAP) rates and extubation outcome were reported by some studies although far less frequently than short-term outcomes. Understandably, these longer-term outcome measures have been a focus of systematic reviews (8, 13, 15, 49). With the exception of mortality (49), systematic reviews included in this scoping review report no significant effect of airway clearance techniques on any of these longer-term outcome measures (8, 13, 15).

This scoping review retrieved a number of experimental studies reporting reduced VAP rates with airway clearance adjuncts (30, 50), head-down positioning (43), manual techniques (51) and multi-modal chest physiotherapy (34, 52). Similarly, an improved likelihood of extubation success has been reported in some studies with cough augmentation (53) and multi-modal chest physiotherapy (54). Whilst quality was not assessed as part of this scoping review, these findings suggest that the effect of airway clearance techniques on VAP rates and extubation outcome may warrant further investigation.

Limitations of this scoping review

This scoping review was intentionally limited to airway clearance techniques that are typically delivered by respiratory physiotherapists in the adult ICU. Due to this, some aspects of airway clearance such as routine suctioning, humidification, regular repositioning, bronchoscopy and pharmacological interventions were not included.

A major methodological limitation was the lack of quality assessment of the included papers. Due to the wide-ranging remit of the review and number of papers retrieved, this was beyond the scope of this review and was not deemed necessary in order to meet the aims and objectives set out in advance. Randomised clinical trials were carefully screened and if they failed to meet the criteria for randomisation as described by PEDro (55), they were classified as 'other experimental' studies.

Future research

Future experimental research is still required to determine the effectiveness of airway clearance techniques in the intubated adult. Existing randomised clinical trials have focused on short-term outcomes and therefore a reasonably comprehensive body of evidence is available for common interventions such as hyperinflation and manual techniques in this regard. There are emerging interventions with an increasing evidence-base such as cough augmentation and airway clearance adjuncts. As an outcome measure, PEF appears to be influenced by ACTs, however its relevance to other, more clinical outcomes would benefit from further experimental investigation. Another under-researched area is positioning for airway clearance, despite this being a routinely used intervention for intubated adults (20). A focus for future research should be the effect of airway clearance on longer-term outcomes, particularly VAP rate and extubation success as these appear to be outcomes that may be influenced by ACTs.

Future reviews should be carefully considered and rationalised. There would be merit in an updated systematic review investigating the effect of manual techniques as several recent studies have not yet been captured by such a review. Furthermore, airway clearance adjuncts for the intubated patient have not yet been investigated by systematic review and this may be an area that warrants the same. A plethora of narrative reviews on this topic are already available and therefore any future narrative reviews should have a clear and unique focus.

Conclusion

This scoping review was undertaken as an area of priority for the ACPRC editorial board. The extent of the available evidence regarding airway clearance for intubated adults has been summarised, thus achieving the aim of the scoping review. Included papers were diverse and wide-ranging in their findings. Overall, the evidence-base regarding the efficacy of airway clearance techniques for short-term clinical outcome measures is moderately large. Currently, there is limited evidence regarding their efficacy for longer-term outcome measures. There is a moderate body of evidence reporting that airway clearance techniques are safe for the intubated adult.

Future clinical research should focus on the effects of airway clearance techniques on longer-term outcome measures such as VAP rates and extubation outcome as well as investigating common but under-researched interventions such as positioning. As the quality of the studies was not assessed in this scoping review, future work is needed to develop clinical recommendations based on both short- and long-term efficacy of airway clearance techniques for adults who are intubated.

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Conflicts of interest

There is no conflict of interest in this project.

References

1 Twose P, Jones U, Cornell G. Minimum standards of clinical practice for physiotherapists working in critical care settings in the United Kingdom: A modified Delphi technique. *J Intensive Care Soc.* 2019;20(2):118–131. https://doi.org/10.1177%2F1751143718807019.

2 Piccin V, Calciolari C, Yoshizaki K, Gomes S, Albertini-Yagi C, Dolhnikoff M, Macchione M, Caldini E, Saldiva P, Negri E. Effects of different mechanical ventilation strategies on the mucociliary system. *Intensive Care Med.* 2011;37(1):132–140. https://doi.org/10.1007/s00134-010-2056-5.

3 Beuret P, Roux C, Auclair A, Nourdine K, Kaaki M, Carton MJ. Interest of an objective evaluation of cough during weaning from mechanical ventilation. *Intensive Care Med.* 2009;35(6):1090–1093. https://doi.org/10.1007/s00134-009-1404-9.

4 Malbouisson L, Muller J, Constantin J, Q, Puybasset L, Rouby J, CT Scan ARDS Study Group. Computed tomography assessment of positive end-expiratory pressure-induced alveolar recruitment in patients with acute respiratory distress syndrome. *Am J Respir Crit Care Med.* 2001;163(6):1444–1450. https://doi.org/10.1164/ajrccm.163.6.2005001.

5 Konrad F, Schiener R, Marx T, Georgieff M. Ultrastructure and mucociliary transport of bronchial respiratory epithelium in intubated patients. *Intensive Care Med.* 1995;21(6):482–489. https://doi.org/10.1007/bf01706201.

6 Connolly B, Barclay M, Blackwood B, Bradley J, Anand R, Borthwick M, Chikhani M, Dark P, Shyamsundar M, Warburton J, McAuley D, O'Neill B. Airway clearance techniques and use of mucoactive agents for adult critically ill patients with acute respiratory failure: a qualitative study exploring U.K. physiotherapy practice. *Physiotherapy.* 2020;108:78–87. https://doi.org/10.1016/j.physio.2020.06.003.

7 Skinner EH, Haines KJ, Berney S, Warrillow S, Harrold M, Denehy L. Usual care physiotherapy during acute hospitalization in subjects admitted to the ICU: An observational cohort study. *Respir Care.* 2015;60(10):1476–1485. https://doi.org/10.4187/respcare.04064.

8 Stiller K. Physiotherapy in intensive care: an updated systematic review. *Chest.* 2013;144(3):825–847. https://doi.org/10.1378/chest.12-2930.

9 Intensive Care Society. *Guidelines for the provision of intensive care services.* 2nd ed. 2019.

10 Borges LF, Saraiva MS, Saraiva MAS, Macagnan FE, Kessler A. Expiratory rib cage compression in mechanically ventilated adults: systematic review with meta-analysis. *Rev Bras Ter Intensiva.* 2017;29(1):96–104. https://doi.org/10.5935/0103-507x.20170014.

11 Anderson A, Alexanders J, Sinani C, Hayes S, Fogarty M. Effects of ventilator vs manual hyperinflation in adults receiving mechanical ventilation: a systematic review of randomised clinical trials. *Physiotherapy.* 2015;101(2):103–110. https://doi.org/10.1016/j.physio.2014.07.006.

12 Paulus F, Binnekade JM, Vroom MB, Schultz MJ. Benefits and risks of manual hyperinflation in intubated and mechanically ventilated intensive care unit patients: a systematic review. *Crit Care.* 2012;16(4):R145. Published 2012 Aug 3. https://doi.org/10.1186/cc11457.

13 van der Lee L, Hill AM, Jacques A, Patman S. Efficacy of respiratory physiotherapy interventions for intubated and mechanically ventilated adults with pneumonia: A systematic review and meta-analysis. *Physiother Can.* 2021;73(1):6–18. https://doi.org/10.3138/ptc-2019-0025.

14 Newman A, Gravesande J, Rotella S, Wu S, Topp-Nguyen N, Kho M, Harris J, Fox-Robichaud A, Solomon P. Physiotherapy in the neurotrauma intensive care unit: A scoping review. *J Crit Care.* 2018;48:390–406. https://doi.org/10.1016/j.jcrc.2018.09.037.

15 Wang MY, Pan L, Hu XJ. Chest physiotherapy for the prevention of ventilator-associated pneumonia: A meta-analysis. *Am J Infect Control.* 2019;47(7):755–760. https://doi.org/10.1016/j.ajic.2018.12.015.

16 Berry MP, Martí JD. Clinical management of secretion retention in critically ill patients who are intubated and mechanically ventilated. *Curr Respir Med Rev.* 2014;10(3):163–75.

17 Peters M, McInerney P, Munn Z, Tricco AC, Khalil, H. Chapter 11: Scoping Reviews. In: Aromataris E Munn Z, (Editors). *JBI Manual for Evidence Synthesis.* JBI; 2020. https://doi.org/10.46658/JBIMES-20-12.

18 Bhat A, Chakravarthy K, Rao BK. Chest physiotherapy techniques in neurological intensive care units of India: A survey. *Indian J Crit Care Med.* 2014;18(6):363–368. https://doi.org/10.4103/0972-5229.133890.

19 Lottering M, Van Aswegen H. Physiotherapy practice in South African intensive care units. *Southern African Journal of Critical Care.* 2016;32(1):11–6. http://www.sajcc.org.za/index.php/SAJCC/article/view/248.

20 Matilde I, Eid R, Nunes A, Ambrozin A, Moura R, Carnieli-Cazati D, Timenetsky K. Bronchial hygiene techniques in patients on mechanical ventilation: what are used and why? *Einstein (Sao Paulo).* 2018;16(1):eAO3856. https://doi.org/10.1590/s1679-45082018ao3856.

21 van der Lee L, Hill AM, 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):230–243. https://doi.org/10.1111/jep.13077.

22 Rose L, Adhikari NK, Poon J, Leasa D, McKim DA; CANuVENT Group. Cough augmentation techniques in the critically ill: A Canadian national Survey. *Respir Care.* 2016;61(10):1360–1368. https://doi.org/10.4187/respcare.04775.

23 Hayes K, Seller D, Webb M, Hodgson C, Holland A. Ventilator hyperinflation: a survey of current physiotherapy practice in Australia and New Zealand. *New Zealand Journal of Physiotherapy.* 2011;39(3):124–30. https://www.proquest.com/openview/4037de7d628e4f38070f49f71b6815d5/1.

24 Stilma W, van der Hoeven SM, Scholte Op Reimer WJM, Schultz MJ, Rose L, Paulus F. Airway care interventions for invasively ventilated critically ill adults – A Dutch national survey. *J Clin Med.* 2021;10(15):3381. Published 2021 Jul 30. https://doi.org/10.3390/jcm10153381.

25 van der Lee L, Hill AM, Patman S. Clinical validation of expert consensus statements for respiratory physiotherapy management of invasively ventilated adults with community-acquired pneumonia: A qualitative study. *Intensive Crit Care Nurs.* 2020;60:102854. https://doi.org/10.1016/j.iccn.2020.102854.

26 Skinner EH, Thomas P, Reeve JC, Patman S. Minimum standards of clinical practice for physiotherapists working in critical care settings in Australia and New Zealand: A modified Delphi technique. *Physiother Theory Pract.* 2016;32(6):468–482. https://doi.org/10.3109/09593985.2016.1145311.

27 Chicayban LM, Zin WA, Guimarães FS. Can the flutter valve improve respiratory mechanics and sputum production in mechanically ventilated patients? A randomized crossover trial. *Heart Lung.* 2011;40(6):545–553. https://doi.org/10.1016/j.hrtlng.2011.05.008.

28 Jones CU, Kluayhomthong S, Chaisuksant S, Khrisanapant W. Breathing exercise using a new breathing device increases airway secretion clearance in mechanically ventilated patients. *Heart Lung.* 2013;42(3):177–182. https://doi.org/10.1016/j.hrtlng.2012.12.009.

29 Kluayhomthong S, Ubolsakka-Jones C, Domthong P, Reechaipichitkul W, Jones DA. The immediate effects of breathing with oscillated inspiratory and expiratory airflows on secretion clearance in intubated patients with cervical spinal cord injury. *Spinal Cord.* 2019;57(4):308–316. https://doi.org/10.1038/s41393-018-0220-x.

30 Kuyrukluyildiz U, Binici O, Kupeli İ, Erturk N, Gulhan B, Akyol F, Ozcicek A, Onk D, Karabakan G. What is the best pulmonary physiotherapy method in ICU? *Can Respir J.* 2016;2016:4752467. https://doi.org/10.1155/2016/4752467.

31 Shetty S, Alaparthi G, Krishnan K, Upadya M, Prabhakar A, Baireddy K, Amaravadi S. Comparison of head-down tilt versus flat position on mucus clearance and respiratory mechanics in mechanically ventilated patients: A randomized crossover trial. Critical Reviews in Physical and Rehabilitation

Medicine. 2020;32(1):23–38. https://manipal.pure.elsevier.com/en/publications/comparison-of-head-down-tilt-versus-flat-position-on-mucus-cleara.

32 Naue Wda S, Forgiarini Junior LA, Dias AS, Vieira SR. Chest compression with a higher level of pressure support ventilation: effects on secretion removal, hemodynamics, and respiratory mechanics in patients on mechanical ventilation. *J Bras Pneumol.* 2014;40(1):55–60. https://doi.org/10.1590/s1806-37132014000100008.

33 Malekzadeh J, Yazdani M, Sedaghat A, Mazlom S.R. Effect of lung manual hyperinflation (MHI) on oxygenation of patients following abdominal surgery and t-tube support. *Evidence Based Care*, 2016;6(3): 55–66. https://doi.org/10.22038/ebcj.2016.7663.

34 Mohamed M, Hagag A, Taha M, Ahmed A. Chest physiotherapy in prevention of hospital acquired pneumonia after liver transplantation. *Medical Journal of Cairo University.* 2017;85(7):2761–8. https://www.semanticscholar.org/paper/Chest-Physiotherapy-in-Prevention-of-Hospital-after-Mohamed-Hagag/e579457733e1d31fb42754a5558284df65a56763.

35 Frank U, Frank K, Zimmermann H. Effects of respiratory therapy (bagging) on respiratory function, swallowing frequency and vigilance in tracheotomized patients in early neurorehabilitation. *Pneumologie.* 2015;69(7):394–399. https://doi.org/10.1055/s-0034-1392359.

36 El-Deen H, Ahmed K. Acute response of manual hyperinflation technique on airway secretion clearance in postoperative Intubated patients. *Journal of Medical Research and Practice.* 2013;2(9):238–45. https://www.researchgate.net/publication/313730498_Acute_response_of_manual_hyperinflation_technique_on_airway_secretion_clearance_in_postoperative_Intubated_patients.

37 Ibrahim A, Mohamed A. Effect of adding different physiotherapy modalities to standard chest physiotherapy for critical ill patients. *Research Journal of Pharmaceutical, Biological and Chemical Sciences.* 2018;9(3):144–52. https://www.researchgate.net/publication/330113790_Effect_of_Adding_Different_Physiotherapy_Modalities_to_Standard_Chest_Physiotherapy_for_Critical_Ill_Patients.

38 Raafat A, Elbasiouny H. Arterial oxygenation response to manual hyperinflation as an added procedure to chest physiotherapy incritically ill mechanically ventilated patients. *Journal of American Science.* 2011;7(12):585–90. http://www.lib.pt.cu.edu.eg/6-Amany%20July%202008.pdf.

39 Waqas M, Malik A, Javed M. Effectiveness of conventional chest physiotherapy versus manual hyperinflation during postural drainage of ventilated COPD patients. *Rawal Medical Journal.* 2014;39(1):32–4. https://www.rmj.org.pk/fulltext/27-1377240720.pdf.

40 Andrews J, Sathe NA, Krishnaswami S, McPheeters ML. Nonpharmacologic airway clearance techniques in hospitalized patients: a systematic review. *Respir Care.* 2013;58(12):2160–2186. https://doi.org/10.4187/respcare.02704.

41 Chuang ML, Chou YL, Lee CY, Huang SF. Instantaneous responses to high-frequency chest wall oscillation in patients with acute pneumonic respiratory failure receiving mechanical ventilation: A randomized controlled study. *Medicine (Baltimore).* 2017;96(9):e5912. https://doi.org/10.1097/md.0000000000005912.

42 Longhini F, Bruni A, Garofalo E, Ronco C, Gusmano A, Cammarota G, Pasin L, Frigerio P, Chiumello D, Navalesi P. Chest physiotherapy improves lung aeration in hypersecretive critically ill patients: a pilot randomized physiological study. *Crit Care.* 2020;24(1):479. Published 2020 Aug 3. https://doi.org/10.1186/s13054-020-03198-6.

43 Bassi G, Marti J, Saucedo L, Rigol M, Roca I, Cabanas M, Muñoz L, Ranzani O, Giunta V, Luque N, Esperatti M, Gabarrus A, Fernandez L, Rinaudo M, Ferrer M, Ramirez J, Vila J, Torres A. Gravity predominates over ventilatory pattern in the prevention of ventilator-associated pneumonia. *Crit Care Med.* 2014;42(9):e620–e627. https://doi.org/10.1097/ccm.0000000000000487.

44 Martí J, Bassi G, Rigol M, Saucedo L, Ranzani O, Esperatti M, Luque N, Ferrer M, Vilaro J, Kolobow T, Torres A. Effects of manual rib cage compressions on expiratory flow and mucus clearance during mechanical ventilation. *Crit Care Med.* 2013;41(3):850–856. https://doi.org/10.1097/ccm.0b013e3182711b52.

45 Amaral BLR, de Figueiredo AB, Lorena DM, Oliveira ACO, Carvalho NC, Volpe MS. Effects of ventilation mode and manual chest compression on flow bias during the positive end- and zero end-expiratory pressure manoeuvre in mechanically ventilated patients: a randomised crossover trial. *Physiotherapy.* 2020;106:145–153. https://doi.org/10.1016/j.physio.2018.12.007.

46 Oliveira ACO, Lorena DM, Gomes LC, Amaral BLR, Volpe MS. Effects of manual chest compression on expiratory flow bias during the positive end-expiratory pressure-zero end-expiratory pressure maneuver in patients on mechanical ventilation. *J Bras Pneumol.* 2019;45(3):e20180058. Published 2019 Mar 11. https://doi.org/10.1590/1806-3713/e20180058.

47 Blattner CN, Santos RSD, Dias FS, Dias AS, Mestriner RG, Vieira SRR. Acute bag-valve breathing maneuvers plus manual chest compression is safe during stable septic shock: a randomized clinical trial. *Rev Bras Ter Intensiva.* 2017;29(1):14–22. https://doi.org/10.5935/0103-507x.20170004.

48 Ferreira LL, Valenti VE, Vanderlei LC. Chest physiotherapy on intracranial pressure of critically ill patients admitted to the intensive care unit: a systematic review. *Rev Bras Ter Intensiva.* 2013;25(4):327–333. https://doi.org/10.5935/0103-507x.20130055.

49 Pozuelo-Carrascosa DP, Torres-Costoso A, Alvarez-Bueno C, Cavero-Redondo I, López Muñoz P, Martínez-Vizcaíno V. Multimodality respiratory physiotherapy reduces mortality but may not prevent ventilator-associated pneumonia or reduce length of stay in the intensive care unit: a systematic review. *J Physiother.* 2018;64(4):222–228. https://doi.org/10.1016/j.jphys.2018.08.005.

50 Spapen H, Borremans M, Diltoer M, De Regt J, Bruggemans C, Honoré PM. Intrapulmonary percussion with autogenic drainage and ventilator-associated gram-negative infection: A pilot study. *Netherlands Journal of Critical Care.* 2016;24(2):6–10. https://www.researchgate.net/publication/299454877_Intrapulmonary_percussion_with_autogenic_drainage_and_ventilator-associated_gram-negative_infection_A_pilot_study.

51 El-Hamid G, Shams T, Ali A, Awad S. Effect of using different modalities of chest physiotherapy on prevention of ventilator associated pneumonia. *Journal of Nursing and Health Science.* 2017;6(5):19–35. https://www.iosrjournals.org/iosr-jnhs/papers/vol6-issue5/Version-7/C0605071935.pdf.

52 Pattanshetty RB, Gaude GS. Effect of multimodality chest physiotherapy on the rate of recovery and prevention of complications in patients with mechanical ventilation: a prospective study in medical and surgical intensive care units. *Indian J Med Sci.* 2011;65(5):175–185. https://doi.org/10.4103/0972-5229.68218.

53 Gonçalves MR, Honrado T, Winck JC, Paiva JA. Effects of mechanical insufflation-exsufflation in preventing respiratory failure after extubation: a randomized controlled trial. *Crit Care.* 2012;16(2):R48. Published 2012 Dec 12. https://doi.org/10.1186/cc11249.

54 Wang TH, Wu CP, Wang LY. Chest physiotherapy with early mobilization may improve extubation outcome in critically ill patients in the intensive care units. *Clin Respir J.* 2018;12(11):2613–2621. https://doi.org/10.1111/crj.12965.

55 de Morton NA. The PEDro scale is a valid measure of the methodological quality of clinical trials: a demographic study. *Aust J Physiother.* 2009;55(2):129–133. https://doi.org/10.1016/s0004-9514(09)70043-1.