Review Article

Chest physiotherapy in mechanically ventilated patients without pneumonia—a narrative review

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Abstract: A beneficial adjuvant role of chest physiotherapy (CPT) to promote airway clearance, alveolar recruitment, and ventilation/perfusion matching in mechanically ventilated (MV) patients with pneumonia or relapsing lung atelectasis is commonly accepted. However, doubt prevails regarding the usefulness of applying routine CPT in MV subjects with no such lung diseases. In-depth narrative review based on a literature search for prospective randomized trials comparing CPT with a non-CPT strategy in adult patients ventilated for at least 48 h. Six relevant studies were identified. Sample size was small. Various CPT modalities were used including body positioning, manual chest manipulation (mobilization, percussion, vibration, and compression), and specific techniques such as lung hyperinflation and intrapulmonary percussion. Control subjects mostly received general nursing care and tracheal suction. In general, CPT was safe and supportive, yet had debatable or no significant impact on any relevant patient outcome parameter, including pneumonia. Current evidence does not support "prophylactic" CPT in adult MV patients without pneumonia.

Keywords: Chest physiotherapy (CPT); mechanical ventilation; intensive care unit (ICU); ventilator-associated pneumonia (VAP); ventilator-associated infectious complications

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Introduction

Chest physiotherapy (CPT) is acclaimed as an important constituent of respiratory care in all mechanically ventilated (MV) critically ill patients, even in the absence of primary or significant lung disease (1). Tracheal intubation indeed seriously impairs cough reflex and mucociliary escalator function leading to sequestration and impaction of secretions in the lower airways. This exposes MV patients to severe lung complications [i.e., ventilator-associated tracheobronchitis, ventilator-associated pneumonia (VAP), and lung atelectasis], prolongs the weaning process, and may increase mortality (2).

One of the key tasks of the intensive care unit (ICU) physiotherapist in MV patients is to facilitate removal of retained or profuse airway secretions aiming to reduce airway resistance, optimize lung compliance, and decrease the work of breathing. For this purpose, the ICU physiotherapist disposes of a diversified armamentarium of breathing methods, manual techniques, and mechanical devices, used alone or in combination (3). In spite of this theoretical benefit, CPT practice for this indication is far from standardized varying from as-needed airway suctioning over a more intricate "multi-modality" approach to physiotherapist-driven manipulation of the ventilator. Also, the incessant call for protocolized medicine (e.g., creation of unit-specific VAP prevention "bundles") as well as concerns regarding medicolegal responsibilities must be

Table 1 Prospective randomized controlled studies of chest physiotherapy in mechanically ventilated patients without pneumonia

Author (reference)	Patients	CPT intervention	Result
Ntoumenopoulos (4)	22 CPT, 24 controls	MLH, postural drainage; bid	No difference in VAP incidence and duration of ventilation between groups
Ntoumenopoulos (5)	24 CPT, 36 controls	Body positioning, expiratory chest wall vibrations, suction; bid	Less VAP in CPT group
Templeton & Palazzo (6)	87 CPT, 85 controls	Body positioning, MLH, rib springing, chest wall vibration, suction; bid	Tendency for more VAP and prolonged ventilation in CPT group
Pattanshetty & Gaude (7)	87 CPT, 86 controls	Body positioning, MLH, chest wall vibrations, suction; bid (controls: MLH and suction)	No difference in VAP incidence between groups; prolonged hospitalization in CPT group
Patman (8)	72 CPT, 72 controls	Body positioning, MLH, suction; 6 times/day	No significant difference between groups for any outcome
Spapen (9)	15 CPT	Body positioning, chest wall vibrations, suction; bid	Tendency for less Gram-negative IVACs in IPV-AADP-treated patients
	15 no CPT	Mobilisation, suction; bid	
	15 IPV-AADP	20 min IPV-AADP sessions, suction; bid	

CPT, chest physiotherapy; MLH, manual lung hyperinflation; VAP, ventilator-associated pneumonia; IPV-AADP, intrapulmonary percussive ventilation-assisted autogenic drainage physiotherapy; IVACs, infection-related ventilator-associated complications; bid, twice daily.

considered when defining the role of such "routine" daily physiotherapy.

What is the evidence for CPT in MV patients without pneumonia?

A literature search for prospective trials that randomly compared adjuvant CPT with no CPT in adult critically ill patients that were ventilated for at least 48 h identified six relevant studies which were summarized in *Table 1*.

Ntoumenopoulos *et al.* studied 46 trauma patients (4). Twenty-two subjects received CPT consisting of two-times daily manual lung hyperinflation and postural drainage. Control patients were turned in bed and aspirated every two hours. No difference was observed in VAP incidence and duration of ventilation. The same investigators subsequently focused on a mixed ICU population of medical, surgical, and trauma patients (5). The treatment group (n=24) received twice-daily sessions of postural drainage or side-lying positioning, expiratory chest wall vibration, and suctioning whilst control patients (n=36) were occasionally mobilized and suctioned by the nursing staff. The major finding was less VAP, defined by the clinical pulmonary infection score (CPIS), in the CPT group (2 *vs.* 14 patients; P=0.01). CPT did not influence duration of ventilation or ICU stay and had no impact on mortality. Points of criticism were the higher number of tracheostomized patients in the control group (17 *vs.* 7 patients; P=0.19) and the poor diagnostic accuracy of the CPIS as surrogate measure for VAP [pooled specificity and sensitivity of respectively 0.65 and 0.64 (10)].

Templeton and Palazzo studied a cohort of 172 medical, surgical, and trauma patients (6). Eighty-seven patients received CPT (body positioning, manual lung hyperinflation, chest wall compression and vibration, suctioning). The 85 control patients were mobilized and aspirated. CPT-treated subjects tended to develop more VAP than controls (35 *vs.* 25 patients; P=0.1). In addition, the CPT group remained longer ventilator-dependent (median: 15 *vs.* 11 days till extubation; P=0.041). ICU length of stay and mortality were not different between groups. This study presented some conspicuous flaws including an important time gap (7 years) between study closure and publication, inclusion of 17% patients with "respiratory failure due to infection", a questionable randomization process, and trends for increased tracheostomy usage (P=0.12), a higher disease severity (P=0.10), and more organ failure (P=0.22) in the CPT group.

Pattanshetty and Gaude studied 173 medico-surgical patients (87 CPT *vs.* 86 controls) (7). The CPT method was comparable with the previous studies, yet the control group also received manual lung hyperinflation. VAP incidence and duration of ventilation did not differ between CPT and control patients. Moreover, CPT subjects had a prolonged hospital stay.

Patman *et al.* studied intensified CPT (i.e., six-times daily posturing, manual lung hyperinflation, and suctioning) in patients with cerebral trauma (8). Seventy-two patients received this CPT whereas those serving as controls were only aspirated. VAP was initially defined by CPIS. When this score equaled or exceeded 7, quantitative cultures were obtained by non-bronchoscopic lavage. The study found no difference in VAP incidence, duration of ventilation or ICU stay, and mortality.

Two RCTs investigated CPT using intrapulmonary percussive ventilation (IPV) (9,11). Clini *et al.* investigated CPT with and without IPV in 46 consecutive tracheostomized patients (11). Subjects received either one-hour CPT, twice daily or CPT of same duration plus two 10-minute IPV sessions. During the 15 day-treatment period, the group that additionally received IPV (n=24) had less pneumonia (6 *vs.* 12 patients) and a progressive improvement in oxygenation and respiratory muscle performance. However, this study did not enroll ICU patients but patients referred to specialized "weaning units". Type of CPT, diagnosis of pneumonia, and concomitant pneumonia prevention measures were not specified. Most importantly, since only patients on spontaneous unassisted breathing completed the study, its results cannot be withheld as relevant for MV subjects. Spapen *et al.* (9) prospectively studied IPV-based CPT in a mixed ICU population. At study enrollment, all patients had normal chest X-rays and airways free of bacterial colonization or infection. Patients were randomized into three groups. A control group was mobilized in bed and aspirated. A second group received CPT consisting of twice-daily body positioning, chest wall percussion and vibration, and suctioning. A third cohort underwent similar twice-daily CPT plus 20 minutes IPV and assisted autogenic drainage (AAD). CPT with and without IPV-AAD physiotherapy was performed by two dedicated physiotherapists on a 24/7 basis. VAP prevention measures were similar in all patients. Forty-five patients were enrolled with 15 subjects included in each group. Study endpoint was a documented Gram-negative infection-related ventilator-associated complication (IVAC), according to the Centers of Disease Control 2011 Working Group Guidelines (12). Gram-negative IVACs were diagnosed in two (13%) patients in the IPV-AAD group and in seven (47%) patients in each of the other groups (P=0.1; IPV-AAD *vs.* CPT and control group). Bias could have been introduced by a great heterogeneity in admission diagnoses, concomitant antibiotic therapy for non-pulmonary infectious disease, differences in enteral nutrition policy, the significantly younger age of the IPV-AAD treated patients, and the poor correlation between IVAC and true VAP. Half of the included patients had acute cerebral pathology which rendered evaluation of outcome variables such as duration of MV or ICU stay irrelevant.

What are the principles, expected benefits, risks, and points for attention of the different CPT techniques used in MV patients?

In all studies, the CPT arm consisted of various combinations of body positioning, chest wall vibration or compression, and manual lung hyperinflation. One study used IPV-ADD as CPT in one of the comparator arms. Control patients mostly received standard nursing care and airway suctioning.

All CPT techniques aimed to dislodge secretions and to facilitate their transport in and removal from the airways. Body positioning and chest mobilization included frequent posture changes, maintenance of a 30° upright position most of the time, in-bed rotations, proper chest alignment, and passive range-of-motion limb exercises. Another major CPT goal was to improve gas exchange and oxygenation by enhancing alveolar ventilation, augmenting ventilation/perfusion matching, and redistributing body fluid on a gravitational basis. Standardized protocols for chest mobilization, however, do not exist. Manual lung hyperinflation (aka "bagging" or "bag-squeezing") promotes alveolar recruitment by delivering larger than baseline and peak pressure-limited tidal volumes, thereby enhancing lung compliance and gas exchange. It is also suggested that it mimics a cough so that airway secretions are mobilized towards the larger airways (13). IPV physiotherapy creates a convective gas front to the distal airways by delivering very small bursts of tidal volume within a frequency range of 60 to 600 cycles/minute. As such, temporary alveolar recruitment and ventilation is provided while mucus is cleared from middle-sized airways and propelled cephalad by generating peak expiratory flows that largely exceed inspiratory flows (14). The effect of IPV is enhanced by adding ADD whereby secretions are loosened and collected at low to mid lung volumes and subsequently expelled by the IPV expiratory flow. IPV was found to be as effective as "standard care" CPT for improving lung function and enhancing sputum expectoration in ambulatory older children and adults with cystic fibrosis (15). ICU patients thought to benefit from IPV are those with relapsing atelectasis, "copious" secretions, or inhalation injury.

As long as the patient's hemodynamic and respiratory parameters are stable before the start of CPT, all manual techniques can be safely applied. Intensive chest mobilization may occasionally be complicated by endotracheal tube or intravascular catheter disconnection, hemodynamic intolerance, increased intracranial pressure, and cardiac arrhythmias. Manual hyperinflation and IPV physiotherapy involve disconnecting the patient from the ventilator. Both techniques might significantly interfere with currently used sedation and ventilation protocols and methods (e.g., low level sedation, sedation breaks, gas anesthesia, low tidal volume/high PEEP ventilation, …). Possible physiological side effects of delivered air volume, flow rates and airway pressure must be carefully considered. IPV, in particular, is expensive and handling requires good knowledge of respiratory (patho)physiology because the patient is placed on a dedicated "high-frequency ventilator" device. Driving pressure must be set appropriately and adapted to the patient's chest excursion. During IPV physiotherapy, the patient's heart rate, respiratory rate, blood pressure, pulse oximetry and end-tidal CO_2 must be observed closely for signs of intolerance. Supplemental oxygen must be provided if needed. To minimize the risk of barotrauma, a pressure pop off must be utilized and peak airway pressures carefully monitored. Performing IPV on a 24/7 basis is labor-intensive and necessitates a skilled physiotherapist team operating under close supervision of ICU physicians.

CPT-induced changes in the patient's general, hemodynamic or respiratory condition must be immediately notified and anticipated conveniently. Specific contra-indications for any form of CPT are undrained pneumothorax, shock or severe hemodynamic instability, recent pulmonary surgery, hemoptysis or active pulmonary hemorrhage, unstable chest wall (e.g., multiple rib or vertebral fractures), acute bronchospasm, and increased intracranial pressure.

Do CPT intensity and technique matter?

Castro *et al.* compared at least four daily CPT sessions with one CPT visit over a 6-hour period in 146 patients, 73 in each group (16). CPT comprised body positioning, manual chest percussions, and suctioning in both groups. More intensive CPT resulted in significantly shorter duration of ventilation and ICU stay, less respiratory infections, and a lower mortality. Enthusiasm should be curbed, however, since the study compared CPT in two different hospitals and key clinical parameters such as degree of organ failure, sedation level, and coma scale were significantly or substantially different between patients. Moreover, almost 25% of the enrolled patients had pneumonia as initial diagnosis with less cases (13 *vs.* 21) in the intensive CPT arm.

Apart from patient positioning and mobilization, manual rib cage compression (MRCC) is one of the most practiced CPT techniques in MV patients. Interestingly, the effect of MRCC may highly depend on its correct accomplishment. Unoki *et al.* randomized 31 MV patients to receive CPT either with or without gradual expiratory MRCC (17). Chest compression did not improve removal of secretions and failed to improve oxygenation and ventilation. This study probably is not representative for a general ICU population. In fact, 80% of the initially included patients were not evaluated due to "hemodynamic instability and/or inadequate human resources" and the paper contains a figure depicting the application of MRCC in a non-ventilated subject. In a porcine model, Martí *et al.* compared "hard" with "soft" MRCC (18). All animals were placed in anti-Trendelenburg position. The "hard" method consisted of strong bilateral chest compressions of 1-second duration synchronized with the start of expiration aiming to increase peak expiratory flow. In contrast, "soft" MRCC applied gradual and gentle lower rib-cage compressions (as in the Unoki trial) from mid-up to end-exhalation aiming to prolong expiratory flow. "Hard" MRCC significantly enhanced mucus clearance and tended to improve pulmonary shunt. In contrast, "soft" MRCC was not effective and even was found to be deleterious by significantly worsening static lung elastance and cardiac output. Moreover, critical factors (study population, mode of mechanical ventilation, time of application, expiratory phase synchronization) should be considered when applying MRCC. To date, clinical evidence on the efficacy and safety of MRCC during MV is scant and limited to small cross-over studies. Guimarães *et al.* applied MRCC followed by hyperinflation in 20 hypersecretive MV patients (19). MRCC caused a mild increase in the amount of cleared airway secretions and had no meaningful effect on respiratory mechanics. Gonçalves *et al.* assessed MRCC in 30 MV patients (20). The MRCC protocol consisted of 20 vigorous expiratory chest compressions followed by tracheal aspiration. MRCC evacuated a greater amount of secretions and improved lung compliance without affecting hemodynamics or gas exchange.

Conclusions

To date, there is insufficient evidence-based proof from current literature to support CPT as a distinct part of respiratory care in MV patients without primary pulmonary disease. The reported studies are all small-sized and insufficiently powered, increasing the risk of statistical error. Overall, CPT may procure better "airway hygiene" but its effects on oxygenation and ventilation are ephemeral at the most and it does not beneficially influence relevant ICU outcome parameters. Intensifying CPT has not convincingly been proven superior. The most used CPT techniques are patient positioning, chest manipulation, and manual hyperinflation. However, applied methods of body positioning are not or incidentally discussed in detail and probably considerably differ between studies. Among chest-directed techniques, MRCC is best supported by experimental and preliminary clinical experience. Whether secretions are more adequately mobilized by brief strong expiratory MRCC or by prolonged soft MRCC during the entire respiratory phase needs additional clinical evaluation. Manual hyperinflation and IPV physiotherapy require patient disconnection of the ventilator which may cause unwarranted effects on sedation and ventilation. Both techniques should not be performed routinely but only if considered to be appropriate and useful in selected patients.

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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