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ENDURANCE TRAINING OF THE RESPIRATORY MUSCLES IN CRITICAL ILL PATIENTS ON MECHANICAL VENTILATION

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ABSTRACT

Introduction: Atrophy of the diaphragm muscle has been reported after no more than 18 hours on mechanical ventilation. Inspiratory muscle training and spontaneous breathing trials can be seen as intrusive weaning. We, therefore, hypothesized that endurance training of the diaphragm muscle by systematically reducing pressure support would prepare the patient for weaning.

Method: Adult critically ill patients, mechanically ventilated for more than 24 hours and expected intubated for more than 48 hours in the ICU of Odense University Hospital were enrolled. Demographic data, blood gas, and respiratory function parameters were among the data recorded at the beginning, during and after the training session. A physiotherapist led the intervention and during training, pressure support was reduced with a maximum of 50%.

Results: 20 patients were enrolled. The mean APACHE II score was 21.7. Before training, the pressure support level was 8.5 (5-10) H_2O. 120 minutes after training, the median value remained lower than 7 (5-10) H_2O. The RASS level during the training was 0 (0 to -1). After three days, 16 out of the 20 (80%) patients were successfully extubated and after five days, additionally, two patients were extubated. During the intervention period, two patients died of other causes.

Conclusion: A physiotherapist driven training program is both safe and feasible and could identify patients ready to wean. Reduction in pressure support levels obtained during training could be maintained afterward.

Keywords: Weaning, endurance training, respiratory muscles, pressure support, rehabilitation, physiotherapy

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INTRODUCTION

The treatment of critically ill patients in intensive care units often involves mechanical ventilation, where patients in need of respiratory support are connected to a ventilator for shorter or longer periods. The admission to the intensive care unit (ICU) often results in both loss of physical function and reduced respiratory capacity in the individual patient [1,2].

Studies have reported that the diaphragm responds to immobilization with the same cellular and structural mechanisms as other muscles [3] and that mechanical ventilation is the leading cause of the weakening of the respiratory muscles [3-5].Thus, mechanical ventilation was found associated with diaphragmatic dysfunction [6] and marked atrophy of diaphragm after just 18 hours of inactivity [7]. One study has shown a decrease in diaphragm thickness of 6% per day during the first week [8] and that the most profound loss of muscle mass occurs within the first 5-7 days of mechanical ventilation [5]. Among patients who are discharged from the ICU, diaphragm dysfunction is associated with readmission to the ICU [9].

The diaphragm benefits from specific training, a practice often used by physical therapists. Effectively strengthtraining of the diaphragm can be challenging in critically ill patients. Most ICU studies use "threshold pressure training," where a valve secures a given inspiratory pressure [3,10-13] or "ventilator pressure trigger sensitivity" where the respirator provides resistance [14,15].

Although the literature does not describe discomfort to the patients by the methods used and by Inspiratory Muscle Training (IMT), these methodsor Spontaneous Breathing Trails,[16] where the patients are to some extent prevented from getting air, is deemed too extreme in our clinical practice. "*Also in other intensive care units, clinical experience shows that patients who rely on mechanical ventilation cannot withstand resistance to respiration more than a few seconds at a time*"(personal communication, Dr. Bernie Bisset, University of Canberra, 21.09.2017).

If we can not adequately train the strength of the respiratory muscles, then reducing the ventilator settings could compel the patients into an increase in active respiration. This systematic and controlled approach will act as endurance training and prepare the patient for weaning.

Modern ventilators have several functions. The ventilator can breathe fully for the patient, but the patient can also self-initiate the respiration and get more or less support to maintain acceptable PEEP and pressure support.

In collaboration with the ICU staff at Odense University Hospital, the rehabilitation department planned this feasibility study on endurance training of the diaphragm on patients dependent on mechanical ventilation**.**

The study aimed to evaluate the feasibility of a training program in terms of adherence, identifying patients ready to wean, the occurrence of adverse events and patient acceptance.

Ethics

The study was presented to the local ethical committee. It was accepted that patients indicated consent before training could be started. Weaning and training were both considered a standard part of patient care in the ICU. The project was considered a regular part of patient treatment. The local ethics committee in the region of Southern Denmark accepted that the patients themselves gave oral consent to participate and this was noted in the medical record.

METHODS

Participants

All patients admitted to the ICU were screened by the department's physiotherapists and assessed based on the alertness level (RASS), expected time on the ventilator, age, and bloodgas values. Patients with neurological problems affecting respiration or restrictions on the elevation of the headpiece were excluded.

Data Collection: Baseline data was collected which included age, sex, weight and APACHE II score.

Ventilator and bloodgas values before and after the intervention were collected from the electronic patient system (CIS (Critical Intelligence System) by Daintel) [17]. During the intervention, data were collected by the physiotherapist in charge of the intervention.

Before and during the training sessions, as well as 20 minutes and 2 hours after, data such as ventilation and blood values, BORG CR10 and the ventilator's settings were collected. The collected data was documented in the patient's journals.

Intervention: The training sessions consisted of 1-3 sets of 5-15 minutes and 2 minutes pause between each set. This was done twice daily but only on weekdays due to organizational reasons. During the training sessions, the pressure support was gradually reduced, starting with 25% to a maximum of 50% of the initial pressure support. If the patient had pressure support <5 cm H_2O, the pressure support could be reduced by 2 cm H_2O at a time until 0 cm H_2O. The ventilator used in this study was Dräger Evita XL.

If the patient's respiration rate (RR) was above 35, saturation(SAT) below 90%, or heart rate (HR) over 120, the training session was stopped. If the patient was at or near these limit values, a 10% change could be accepted. There was always an ICU nurse present during the training. If extra oxygen was needed during the training session, the oxygen level could be increased by 10%. After the training session, the pressure support was returned to the starting value. Our aim was for the patients to score 3-4 on a Borg CR10 scale.

The attending physician was informed about how the training had progressed and could assess whether the patient could cope with a permanent reduction in pressure support.

Data analysis: Descriptive data calculated for baseline values were presented with either numbers and percent or medians and interquartile range. Data were compared using the Wilcoxon Rank-sum test and the Chi2 test as appropriate. All tests were performed with Stata/IC (StataCorp. 2011. Stata Statistical Software: Release 12.1. College Station, TX: StataCorp LP) for Windows.

RESULTS

A total of 20 patients were included in the study from October 2017 to April 2018.

The study cohort consisted of 20 patients averaged 73.5 years, 70% female, and a mean weight of 78.5kg. At the start of the intervention, the average RASS score was 0 and they had an Apache II score of 20.5. They averaged a mean pH of 7.41 and lactate of 1.45 mmol/l. The mean ventilator settings were PEEP 9.5cm H_2O and PS 8.5 cm H_2O.

60% were admitted after surgery and 40% with a medical diagnosis. 19 of the 20 patients received mechanical ventilation due to respiratory insufficiency. One had sepsis-related respiratory issues.

Two patients in the study were not able to complete all three sets in one training session due to a RR above 35. Both patients had acceptable blood gas values after the intervention, and the RR was below 35 after a maximum of five minutes. Two of the included patients died during the study period due to causes not related to the intervention.

Age, (year)	73.5 (69-77)
Sex(%) Female Male	 70 30
Weight (kg)	78.5 (73.8-90)
Apache II	20.5 (18-24)
RASS	0 (-1-0)
Reason for admittance, n (%) Medical Surgical	 40 60
pH	7.41 (7.38-7.49)
Lactate (mmol/l)	1.45(1.1-1.7)
PEEP (cm H_2O)	9.5 (6-10)
PS (cm H_2O)	8.5 (5-10)
Data are in median and in 25% and 75% quartiles	

Table 1: Baseline data

The number of training sessions varied from 1 to 11; the median was 4. There was a decrease in PS 2 hours after the first training, with an average of 29%. Patients scored a median of 4 on the Borg CR10 scale and during the study, only two patients did not complete a training session.

Number of training sessions	4 (1-11)
Reduction in PS(%)(cm H_2O)	29 (From 8.5 to 6)
Borg CR10 scale	4 (2-5)
Not completed a training session (n)	2
Data are in %, median and in 25% and 75% quartiles	

Table 2: Overview of training participation, weaning, and patient evaluation

There was detectable lower pressure support after the first training (Figure 1), and 80% of the included patients were extubated after three days.

Figure 1: Pressure support before and after the first training

The PS was reduced by a median of 2.5 cm H_2O from before the first training session until 2 hours after. RR, SAT, and HR all stayed well below the limits set in the study.

PS average reduction of 120 min after training (cm H_2O)	2.5
RR before/120 mins after training	25(22-30)/21(16-29)
SAT before/120 mins after training (%)	95(94-95)/96(94-98)
HR before/120 mins after training	96(82-102)/95(73.5-108.5)
Data are in median and in 25% and 75% quartiles	

Table 3: Pressure support and cut off values before and after 120 mins after training

DISCUSSION

This study aimed to evaluate the feasibility of endurance training while the patients were on mechanical ventilation. Not to assess the correct duration of the training or the exact amount to reduce the pressure support. There was a high level of patient acceptability and only two patients exceeded the maximum RR of 35. Over 50% of the patients could indicate the training intensity on a BORGS CR10 with a median of 4. The average reduction in PS was 1.4 cm H_2O after 2 hours.

In the literature, precise time intervals for strength training and endurance training have not been reported earlier. One can, therefore, speculate whether the duration of training sessions and the reduction in pressure support has been large enough to challenge all patients. Also one could speculate whether the results obtained in this trial have been affected by the fact that the ICU doesn't have a standard weaning protocol but relies on the attending physician's evaluation and preferences.

In this study, we only choose to change pressure support. This was done to avoid changes in too many variables that could blur the result. However, it could be interesting to work with a reduction in PEEP either alone or in combination with reduction of pressure support. A large number of patients were excluded due to the strict inclusion criteria, mainly lactate being >2.0mmol/l or the pH was <7.35. The inclusion criteria could be changed to include a larger population, since a significant group of the excluded patients, in our opinion, could have received the intervention without any problems.

There was a high level of patient acceptability, and we did not have any patients stop the training sessions during the study. The two times the training sessions were stopped, the physiotherapists did it because of the RR> 35. Neither were there any patients who, when asked, decline to participate in the study.

The only adverse events during the study were the two patients that exceeded the maximum RR of 35. Both of these patients had a RR< 35 within 5 minutes of the ventilator was reset to the initial settings. Both patients could start the next training session within 24 hours and complete the following sets.

The values for stopping the training session were RR>35, SAT > 90%, and an HR >140 only caused the two above mentioned training sessions to be stopped. Since there were no more adverse events, it seems that these limits worked as intended.

11 out of 20 patients could indicate the training intensity on a Borg CR10 scale. The median was 4, which was also in the range that we were aiming at.We found an average reduction in PS of 1.4 CM H_2O 2 hours after the first training. Since this is the first study on this type of training, we have no studies that can support this, but it may indicate that physiotherapists can help to identify patients that can undergo this training and be reduced in PS. Since measuring the correct reduction in PS wasn't the goal of the study, we don't know if this is clinically significant.

Since there were no other studies in this area of training, we had to design the training ourselves. With many years of knowledge of critically ill patients on mechanical ventilation, the multidisciplinary team established parameters of both the duration and the amount of reduction in the pressure support. Studies have investigated other forms of respiratory muscle training, involving a larger inspiratory effort; however, we believe that in our patient population, with a rather high burden of acute illness/high disease severity score, this would be too strenuous, which is why we - based on interdisciplinary consensus - decided on this method for respiratory muscle training.

The physiotherapists, with their professional knowledge of muscle training and lung function, have worked in an area that has until now been taken care of by nurses and doctors. The interdisciplinary interaction is the foundation of the weaning process and here, the physiotherapist can have an important role. In the Nordic countries and several European countries, it is not customary that physiotherapists are actively involved in training the respiratory muscles while the patients are receiving mechanical ventilation. This project indicates that physiotherapists could be more progressive with their role in the weaning process even though it can be a time-consuming process due to the length of the intervention.

CONCLUSION

This study indicates that it is safe and feasible to perform endurance training of the diaphragm while the patient is connected to mechanical ventilation. It is possible that physiotherapists are included more in the weaning process, and it is possible that physiotherapists, through this training, can help identify patients who can begin the weaning process. There were lower pressure support levels after the first training session. This study indicates that screening and diaphragm training sessions in patients receiving mechanical ventilation might achieve a faster reduction of pressure support and accelerate the weaning process.

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REFERENCES

[1] Akansha Dixit, ShashwatPrakash . Effects of threshold inspiratory muscle training versus conventional physiotherapy on the weaning period of mechanically ventilated patients: A comparative study. International Journal of Physiotherapy and Research, Int J Physiother Res 2014, Vol 2(2):424-28.

[2] Snelson C, Jones C, Atkins G, Hodson J, Whitehouse T, Veenith T, Thickett D, Reeves E, McLaughlin A, Cooper L, McWilliams D: A comparison of earlier and enhanced rehabilitation of mechanically ventilated patients in critical care compared to standard care (REHAB): study protocol for a single-site randomised controlled feasibility trial Pilot Feasibility Stud. 2017; 3: 19.

[3] Martin AD, Smith B, Gabrielli A: Mechanical ventilation, diaphragm weakness and weaning: A Rehabilitation Perspective. Respir Physiol Neurobiol. 2013 Nov 1; 189(2):10.1016.

[4] Elkins M, DenticeR.Inspiratorymuscle training facilitates weaning from mechanical ventilation among patients in the intensive care unit: a systematic review. J Physiother. 2015 Jul;61(3):125-34.

[5] Hermans G, Agten A, Testelmans D, Decramer M, Gayan-Ramirez G:Increased duration of mechanical ventilation is associated with decreased diaphragmatic force: a prospective observational studyCrit Care. 2010; 14(4): R127.

[6] Jaber S, Jung B, Matecki S, Petrof BJ. Clinical review: ventilator-induced diaphragmatic dysfunction-human studies confirm animal model findings. Crit Care. 2011 Mar 11;15(2):206.

[7] Levine S, Nguyen T, Taylor N, Friscia ME, Budak MT, Rothenberg P, et al.. Rapid disuse atrophy of diaphragm fibers in mechanically ventilated humans. N Engl J Med. 2008 Mar 27;358(13):1327-35.
[8] Grosu HB, Lee YI, Lee J, Eden E, Eikermann M, Rose KM: Diaphragm muscle thinning in patients who are mechanically ventilated. Chest. 2012 Dec;142(6):1455-1460.
[9] Adler D, Dupuis-Lozeron E, Richard J-C, Janssens J-P, Brochard L. Does inspiratory muscle dysfunction predict readmission after intensive care unit discharge? Am J RespirCrit Care Med. 2014; 190:347-350.
[10] Cader SA, Vale RG, Castro JC, Bacelar SC, Biehl C, Gomes MC, et al. Inspiratory muscle training improves maximal inspiratory pressure and may assist weaning in older intubated patients: a randomised trial. J Physiother. 2010;56:171–177.
[11] Condessa RL, Brauner JS, Saul AL, Baptista M, Silva ACT, Vieira SRR. Inspiratory muscle training did not accelerate weaning from mechanical ventilation but did improve tidal volume and maximal respiratory pressures: a randomised trial. J Physiother. 2013;59:101–107.
[12] Dixit A, Prakash S. Effects of threshold inspiratory muscle training versus conventional physiotherapy on the weaning period of mechanically ventilated patients: a comparative study. Int J Physiother Res. 2014;2:424–428.
[13] 15 Ibrahiem AA, Mohamed AR, Saber HM. Effect of respiratory muscles training in addition to standard chest physiotherapy on mechanically ventilated patients. J Med Res Prac. 2014;3:52–58.
[14] Caruso P, Denari SDC, Al Ruiz S, Bernal K, Manfrin GM, Friedrich C, et al. Inspiratory muscle training is ineffective in mechanically ventilated critically ill patients. Clinics. 2005;60:479–484.
[15] Elbouhy MS, AbdelHalim HA, Hashem AMA. Effect of respiratory muscles training in weaning of mechanically ventilated COPD patients. Egypt J Chest Dis Tuberc. 2014;63:679–687.
[16] http://www.ardsnet.org/files/ventilator_protocol_2008-07.pdf
[17] https://www.daintel.com/uploads/5/9/1/0/59104507/cis_connectivity.pdf