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Respiratory Intra-Cycle Worsening of Pulmonary Hemodynamics during ARDS

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Introduction. Pulmonary hemodynamics worsening during ARDS is frequent and clinically relevant. However, little information exists about how pulmonary hemodynamics changes during the respiratory cycle.

Objectives. To evaluate how pulmonary hemodynamics changes during the respiratory cycle in a porcine model of ARDS.

Methods. 6 pigs were subjected to lung saline lavages followed by 2 h of injurious mechanical ventilation to create a model of ARDS. Pulmonary hemodynamics was evaluated by means of a transonic flow sensor and a high fidelity microtip pressure catheter placed in the pulmonary artery trunk. Signals from these sensors were acquired during a 2 min priod before (Baseline) and 2 h after the ARDS model was established. Mechanical ventilation was set in control volume with PEEP 8cmH2O, tidal volume 6 ml/kg, FiO2 1 and respiratory rate to keep an EtCO2 around 45 mmHg. Pulmonary hemodynamic variables were calculated beat by beat and then subjected to a custom algorithm that allows their evaluation at each moment of the respiratory cycle. This analysis allows expressing how the variables behaves during the whole respiratory cycle, during expiration and how it changes during inspiration.

Results. No differences were found in tidal volume and PEEP between the experimental conditions but driving pressure significantly increased during ARDS when compared with Baseline (18 ± 3 vs 6 ± 1cmH2O, $p < 0.001$). Main results of hemodynamic evaluation are described in Table 1.

Table 1. Expiratory and inspiratory Pulmonary artery hemodynamics

Variable	Baseline	ARDS	p[a]
Stroke Volume (ml)			
Expiratory	38 (3)	33 (6)	**0.046**
Inspiratory	-3 (1)[b]	-3 (1)[b]	0.99
Total	35 (3)	30 (6)	**0.046**
Mean pressure (mmHg)			
Expiratory	19.5 (2.0)	27.3 (4.3)	**0.004**
Inspiratory	-0.5 (0.3)[b]	-0.7 (0.3)[b]	**0.004**
Total	19.1 (2.1)	26.7 (4.2)	**0.004**
Pulse Pressure (mmHg)			
Expiratory	11.9 (4.1)	19.4 (3.6)	**0.007**
Inspiratory	-0.8 (0.4)[b]	-1.5 (0.7)[b]	**0.028**
Total	11.1 (3.8)	17.9 (3.0)	**0.008**
Compliance (ml/cmH_2O)			
Expiratory	3.59 (1.34)	1.77 (0.49)	**0.01**
Inspiratory	-0.07 (0.04)[b]	-0.04 (0.00)[b]	0.169
Total	3.52 (1.32)	1.72 (0.49)	**0.01**
Resistance (dyn.c/cm^{-5})			
Expiratory	483 (120)	682 (198)	0.069
Inspiratory	34 (13)[b]	50 (12)[b]	0.306
Total	517 (130)	732 (222)	0.074
Effective arterial elastance (mmHg/ml)			
Expiratory	0.51 (0.07)	0.84 (0.19)	**0.003**
Inspiratory	0.04 (0.01)[b]	0.08 (0.04)[b]	**0.041**
Total	0.55 (0.08)	0.92 (0.22)	**0.003**

[a] p for the comparison between baseline an ARDS ate the corresponding respiratory stage.
[b] $p < 0.01$ testing if the change during inspiration was significant.

Comparing with Baseline, ARDS decreased stroke volume and pulmonary artery compliance and increased mean pulmonary artery pressure and pulmonary effective arterial elastance (lumped parameter of arterial load) during the whole respiratory cycle and during expiration. Comparing with expiration, inspiration caused a decrease in the pulmonary artery mean and pulse pressure and an increase in pulmonary artery resistance and effective arterial elastance both in Baseline and in ARDS; these inspiratory effects were significantly larger during ARDS than in Baseline for all variables except for resistance.

Conclusion. In this experimental ARDS model, changes in pulmonary hemodynamics caused by breathing during mechanical ventilation were described. Especially, a larger tidal increase in pulmonary arterial load and in consequence a respiratory intra-cycle worsening on pulmonary hemodynamics caused by ARDS was demonstrated. This might be related with mechanics and functional change in the respiratory system cause by ARDS as well as mechanical ventilation.

Reference(s)

1. 2020 Professor Burkhard Lachmann Award for Experimental Research
2. 2012 ESICM ECCRN Basic Science Award

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In silico testing of a non-invasive, individualised PEEP titration method for optimal lung compliance during pressure support ventilation

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Introduction. Comprehensive quantification of respiratory system mechanics during pressure support ventilation (PSV) classically requires invasive measurements or interruptions of spontaneous breathing. This limits broad clinical applicability of these methods for lung compliance optimisation during PSV. Therefore, we present a non-invasive approach for individualised PEEP titration based on dynamic lung compliance measurements at the bedside.

Objectives. This study focuses on the sensitivity of a non-invasive method for bedside quantification of dynamic lung compliance in response to simulated PEEP interventions in patients receiving PSV.

Methods. An individual patient's respiratory system was modelled in Simulink R2020b (The MathWorks, Inc., MA, USA) as an electrical analogue with a pressure dependent lung compliance (Fig. 1a). This in silico patient was ventilated in PSV mode applying 7 different PEEP levels: 0, 2, 4, 6, 8, 10, 12, and 14 cmH2O. Simulations were run during spontaneous breathing at each PEEP level. The expiratory time constant (RC-time = airway resistance * respiratory system compliance = RAW * CRS) was estimated [1]. The airway resistance was determined as the time derivative of the airway pressure divided by the time derivative of the flow, both around zero flow at end-inspiration. CRS was calculated as the RC-time over the median airway resistance over all breaths. The correlation between true, i.e. modelled, and measured compliance was quantified with the Pearson correlation coefficient.

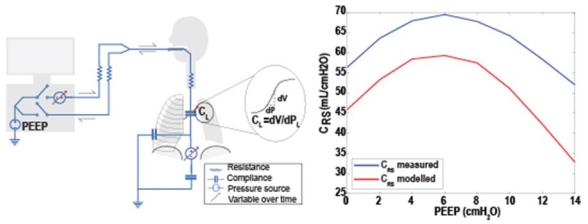

Fig. 1. a) Individual ventilated patient model represented as an electrical analogue. The respiratory system compliance (CRS) is estimated at various PEEP levels, affecting the working point on the lung compliance (CL) curve. b) Respiratory system compliance (CRS): measured (blue), and modelled (red)

Results. Both measured and modelled CRS at each PEEP level are shown in Fig. 1b. The measured compliances correlate well with the modelled compliances ($r = 0.85$, $p < 0.01$), although they show a systematic offset. Importantly, individualised titration of PEEP was possible using the proposed method, as the PEEP level for maximal lung compliance was identical in both curves.
Conclusion. We demonstrate that this method allows for non-invasive, individualised PEEP titration during PSV ventilation in a modelled clinical case. This approach has great potential for future bedside use, and therefore deserves further clinical testing, aiming to optimise pressure support ventilation, and promote patient-ventilator synchrony and weaning.

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000434

A Novel CPAP Weaning Protocol for COVID-19 used across the Critical Care and Respiratory Medicine Interface

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Introduction. COVID-19 was declared a pandemic on the 12th March 2020. Due to the novel nature of the disease and the pressure it forced upon healthcare systems the management of the disease varied. Initially early intubation and ventilation was advised but this rapidly changed due to the volume of patients that required respiratory support. The effectiveness of Continuous Positive Airway Pressure (CPAP) in acute respiratory failure had previously been investigated, prior to the pandemic. This suggested that management of respiratory failure with CPAP contributed to a reduction in several outcomes including length of stay in ICU and the number of patients that required intubation **(1,2).** By April 2020, the National Institution for Health and Care Excellence (NICE) revised guidance recommending CPAP in COVID-19 patients whilst recognising a lack of evidence of its efficacy **(3).** International evidence proposed that hypoxaemic patients with COVID-19 pneumonitis responded well to CPAP which indicated a vital role for its use. In addition to this, using CPAP could reduce the need for intubation and ventilation and therefore reduce the need for advanced respiratory support **(4).** A CPAP weaning protocol was used to guide patient care using intermittent CPAP and high flow nasal oxygen (HFNO) in our District General Hospital (DGH).
Methods. This is a retrospective, observational study conducted at Warrington general hospital in the United Kingdom. In normal circumstances Warrington DGH has a 20 bed ICU. Due to the constraints of COVID-19 the bed base was expanded into theatre recovery. The CPAP weaning protocol was initiated for each patient that was admitted to Intensive Care for CPAP due to COVID-19 pneumonitis. The weaning plan provided guidance for the use of intermittent CPAP and HFNO during breaks. Patient demographics and outcomes were recorded as part of ICNARC data and compared with national statistics. After the demand of the second wave reduced, data was collected through a questionnaire that was completed by the multidisciplinary team (MDT) working on Intensive Care to gain feedback regarding the use of the weaning plan.
Results. The CPAP weaning regimen was used primarily in Intensive care and provided continuity of care when patients were subsequently stepped down to ward level care under the medical team. Local statistics show a mortality rate was 16.6% that was similar to national Figs. 17.8% **(5)**. The median ICU length of stay was 5.5 days (IQR: 3.2, 8.3). Data was collected from the MDT that used the regimen. 94% of staff found the weaning protocol easy to use, and 92.5% felt that it assisted with patient handover. This was particularly important during the pandemic due to the demand on Intensive care it was important to provide consistency and aid communication within the MDT. In times where staffing was stretched, temporary staffing increased and nursing ratios were placed under strain this tool provided guidance for patient care. 97% of users found that it assisted the assessment of patient progress which in turn emphasised flow from Intensive care to ward level care.
Conclusion. This novel CPAP weaning pathway aided continuity of care and assessment of patient progress during their stay in ICU. In our hospital it added clarity to the handover, particularly from intensive care to ward level care. The CPAP weaning plan did involve the use of CPAP in combination with HFNO which may have limited availability in other centres. However, if available could be a useful tool to consider when treating patients with COVID-19 pneumonitis in the future.

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000437

High rate of endotracheal tube occlusions reported in COVID-19 patients: analyse of humidification devices use

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Introduction. High rates of endotracheal tube occlusions have been reported in COVID-19 patients (1–7). Underhumidification of inspiratory gases may explain this complication during prolonged mechanical ventilation(8).
Objectives. To evaluate humidification performances of heat and moisture exchangers and heated humidifiers used in these reports and compare to humidity output according to manufacturers.
Methods. We conducted a bench study with the psychrometric method to evaluate several HME with a previously described method(8): The Hygrobac S (Medtronic, Minneapolis, MN, USA) used at our centre, the Sunmed FH603008 and the Medline DYNJAAHME1B used in Wiles et al. study(4), Intertherm, Intersurgical used in Sugimoto study(6) and Aero-Pro™ HEPA Light Machine and AirLife® Edith 1000 used in Panchamian study(1). We compared to the data of humidity delivered provided by the manufacturers. We also evaluated heated wire heated humidifiers used with ambient temperature at 22–24 °C, 28–30 °C and turned off(7).
Results. Preliminary results are presented, with 2 to 5 measurements done at steady state for each device). Other humidity measurements are ongoing and still NA.