Research Square

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Lung Mechanics in Type L CoVID-19 Pneumonia: A Pseudo-Normal ARDS.

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Abstract

Background.

This study was conceived to provide systematic data about lung mechanics during early phases of CoVID-19 pneumonia, as long as to explore its variations during prone positioning.

Methods.

We enrolled four patients hospitalized in the Intensive Care Unit of “M. Bufalini” hospital, Cesena (Italy); after the positioning of an esophageal balloon, we measured mechanical power, respiratory system and transpulmonary parameters and arterial blood gases every 6 hours, just before decubitus change and 1 hour after prono-supination.

Results.

Both respiratory system and transpulmonary compliance and driving pressure confirmed the pseudo-normal respiratory mechanics of early CoVID-19 pneumonia (respectively, C_{RS} 40.8 ml/cmH_2O and DP_{RS} 9.7 cmH_2O; C_L 53.1 ml/cmH_2O and DP_L 7.9 cmH_2O). Interestingly, prone positioning involved a worsening in respiratory mechanical properties ($C_{RS,SUP}$ 56.3 ml/cmH_2O and $C_{RS,PR}$ 41.5 ml/cmH_2O – P 0.37; $C_{L,SUP}$ 80.8 ml/cmH_2O and $C_{L,PR}$ 53.2 ml/cmH_2O – P 0.23).

Conclusions.

Despite the severe ARDS pattern, respiratory system and lung mechanical properties during CoVID-19 pneumonia are pseudo-normal and tend to worsen during pronation.

Trial registration.

Restrospectively registered.

Background

Since its outbreak, in January, 2020, it has been clear that CoVID-19 pneumonia is atypical. Despite a full concordance to Berlin criteria for Acute Respiratory Distress Syndrome (ARDS), respiratory system mechanics is preserved [1]. Mechanical ventilation and muscular paralysis are recommended in worsening respiratory insufficiency [2]; in a substantial number of cases, prone positioning significantly improves oxygenation.

Little is known about isolated lung behavior in CoVID-19 pneumonia. Hence, the aim of this study is to analyze lung mechanical properties in the first hours after the beginning of mechanical ventilation and in prone and supine position.

Methods

A retrospective observational study was performed at Maurizio Bufalini hospital (Cesena, Italy). Patients hospitalized in the Intensive Care Unit (ICU) from 03/23/2020 to 04/10/2020 were enrolled. The inclusion criteria were: age > 18 years, need of mechanical ventilation, need of muscular paralysis and < 48 hours of tracheal intubation.

After admission in ICU, a naso-gastric tube with an esophageal balloon (Nutrivent® - SEDA S.p.A., Mirandola, Italy) was positioned; the correct positioning and insufflation volume were tested with the occlusion method and measures were recorded with a multiparametric monitor connected to esophageal balloon and ventilator circuit (Optivent® – SEDA S.p.A., Mirandola, Italy).

Protective ventilation, defined as tidal volume (V_t) of 5–7 ml/kg predicted body weight (PBW), was used. Respiratory rate (RR) was set to tolerate mild hypercarbia (p_aCO_2 <60 mmHg) and/or pH > 7.25.

Measures were performed at admission, then every six hours or just before placing patients in prone or supine position and one hour after the change of decubitus. An arterial blood gas sample was collected along with every evaluation. We stopped measuring when muscular paralysis was suspended. Ventilator settings were recorded; static parameters were obtained through a 3 seconds inspiratory and expiratory hold. Airway (P_{AW}) and esophageal (P_{ES}) pressure values were recorded and the latter was used to calculate transpulmonary pressure (P_L), as the result of the real-time subtraction of P_{ES} to P_{AW}. Subsequently, compliance (C_{RS}, C_L), driving pressure (DP_{RS}, DP_L) and mechanical power (MP_{RS}, MP_L) related both to respiratory system and lung were calculated [3].

Results

We report data of four consecutive patients who fulfilled the inclusion criteria; two more patients were enrolled and excluded from the analysis – one died and the other was suspended myoresolution after enrollment. In all patients, chest computed tomography (CT) showed interstitial pneumonia without loss of parenchymal aeration; patients were put on mechanical ventilation within 24 hours of hospital admission. In Table 1 are summarized the main clinical and ventilatory features for every patient.

Table 1
Clinical features, ventilator settings and mechanical measurements of individual patients, in supine and prone position. BMI: Body Mass Index; I:E: inspiratory-to-expiratory ratio; PEEP: Positive End-Expiratory Pressure; P_{plat}: plateau pressure; $PEEP_{tot}$: total PEEP; DP_{RS}: Respiratory System Driving Pressure; C_{RS}: Respiratory System Compliance; MP_{RS}: Respiratory System Mechanical Power; $P_{L,end\ insp}$: Transpulmonary Pressure at end inspiration; $P_{L,end\ exp}$: Transpulmonary Pressure at end expiration; DP_L: Transpulmonary Driving Pressure; C_L: Transpulmonary Compliance; MP_L: Transpulmonary Mechanical Power; p_aO_2: oxygen arterial partial pressure; F_IO_2: inspired fraction of oxygen; p_aCO_2: carbon-dioxide arterial partial pressure; A-aO_2 gradient: alveolar-to-arterial oxygen gradient; $EtCO_2/p_aCO_2$ ratio: end-tidal CO_2 to p_aCO_2 ratio.

	Patient 1		***Patient 2***	***Patient 3***		***Patient 4***		
	Supine	Prone	Supine	Prone	Supine	Prone	Supine	Prone
	Median (IQR)	Median (IQR)	Median (IQR)	Median (IQR)	Median (IQR)	Median (IQR)	Median (IQR)	Median (IQR)
Clinical features								
Age	67		43	75		65		
Sex	M		M	F		M		
BMI (kg/m^2)	24.5		28,4	31,3		24,8		
Comorbidities	No		No	BPCO		No		
Ventilator settings								
Tidal volume (ml/PBW)	5.9 (0)	6.2 (0.04)	6.1 (0.3)	5.9 (0)	7.4 (0.1)	7,4 (0)	5.6 (0.2)	5.6 (0)
Respiratory rate (bpm)	22 (4.5)	19.5 (2.5)	20 (0.3)	20 (0)	20 (0)	20 (0)	28 (5)	25 (8)
I:E (sec)	0.51 (0.2)	0.48 (0.11)	0.56 (0.11)	0.64 (0.13)	0.5 (0)	0.5 (0)	0.43 (0.07)	0.53 (0.07)
PEEP (cmH_2O)	12 (3)	12 (0)	10 (1)	11 (1)	14 (0)	14 (0)	10 (2)	12 (0)
Respiratory system mechanics								
P_{plat} (cmH_2O)	19 (3)	20 (2.1)	21.8 (2.3)	21.5 (1.5)	23.6 (0.6)	24.7 (0.3)	23 (2.3)	27 (3)
$PEEP_{tot}$ (cmH_2O)	12.4 (2.5)	12.7 (0.4)	10.9 (0.9)	11.7 (1.3)	14.9 (0.2)	14.9 (0.1)	11 (3.7)	13 (2)
DP_{RS} (cmH_2O)	7 (0.7)	7.8 (1.4)	10.9 (1.4)	9.8 (0.2)	8.7 (0.7)	9.8 (0.3)	12 (1.8)	13.8 (1)

	Patient 1		*Patient 2*	*Patient 3*		*Patient 4*		
C_{RS} (ml/cmH_2O)	60.1 (6.3)	57.2 (17.7)	38.3 (3.6)	39.8 (0.8)	44.6 (4.2)	40 (1)	35.4 (4.7)	33.1 (2.3)
MP_{RS} (J/min)	16.9 (4.8)	16.4 (2)	15.7 (3.3)	15.8 (2.3)	17.9 (0.1)	18.2 (0)	25.6 (7.2)	27.6 (8.8)
Lung mechanics								
P_L, end insp (cmH_2O)	8.2 (3.2)	7.9 (3)	13.5 (2.2)	16 (1.9)	11.4 (2.6)	15.3 (0.2)	14.3 (1.5)	19.6 (7.6)
P_L, end exp (cmH_2O)	4.4 (2.2)	3 (1.5)	4.4 (2)	7.6 (1.6)	6.1 (2.1)	7.7 (0.5)	5.4 (1.7)	7.9 (5.8)
DP_L (cmH_2O)	4.4 (2.4)	5.2 (2.1)	9.2 (1.5)	8.4 (0.3)	5.4 (0.6)	7.6 (0.6)	8.8 (2.3)	11.5 (1.4)
C_L (ml/cmH_2O)	100.4 (54.5)	81.5 (23.3)	45.2 (7.4)	46.5 (1.7)	72.8 (8.4)	51.6 (4.1)	47.7 (9.6)	39.3 (4.6)
MP_L (J/min)	11.8 (2.5)	12.4 (1.2)	12.2 (1.6)	11.6 (0.9)	12.6 (0)	13.6 (0.2)	16.6 (4)	20.1 (6.8)
Blood gas analysis								
P_aO_2 (mmHg)	90.6 (13.3)	84.6 (53.6)	75.3 (16.8)	82.3 (12.4)	141.8 (54)	164.6 (16.9)	64.5 (17.8)	75.9 (16.9)
F_IO_2 (%)	80 (22.5)	75 (17.5)	50 (2.5)	50 (0)	77.5 (22.5)	70 ()	80 (10)	80 (5)
P_aCO_2 (mmHg)	68 (12.1)	58.1 (10.1)	50.4 (1.5)	40.6 (0.2)	53 (5.6)	45.3 (5.3)	52.1 (7.7)	53 (10.3)
pH	7.23 (0.05)	7.28 (0.06)	7.38 (0.03)	7.41 (0.01)	7.35 (0.04)	7.37 (0)	7.22 (0.05)	7.24 (0.06)
A-aO_2 gradient (mmHg)	386.6 (153.1)	325.7 (47.1)	219.5 (5.3)	223.5 (12.2)	344.6 (113.4)	277.9 (35.2)	372.5 (71)	433.9 (82.3)
$EtCO_2/p_aCO_2$ ratio	0.51 (0.09)	0.68 (0.25)	0.84 (0.03)	0.84 (0)	0.64 (0.05)	0.74 (0.19)	0.58 (0.06)	0.57 (0.01)

The median time of observation was 54.5 hours. Patients underwent 1.5 median cycles of prono-supination, for a median pronation time of 30 hours. Median V_t was 5.9 ml/kg PBW and median RR was 20 breaths per minute; MP_{RS} was 17.9 J/min, while MP_L was 13.1 J/min. Median C_{RS} and DP_{RS} were, respectively, 40.8 ml/cmH_2O and 9.7 cmH_2O. The same parameters, calculated using the transpulmonary pressure, led to a median C_L of 53.1 ml/cmH_2O and a median DP_L of 7.9 cmH_2O.

No statistically significant variation was observed in respiratory system ($C_{RS,SUP}$ 56.3 ml/cmH_2O; $C_{RS,PR}$ 41.5 ml/cmH_2O – P 0.37) and lung ($C_{L,SUP}$ 80.8 ml/cmH_2O; $C_{L,PR}$ 53.2 ml/cmH_2O – P 0.23) mechanics during prone positioning.

Discussion

CoVID-19 pneumonia is peculiar: despite a severe hypoxemia, respiratory system mechanics is pseudo-normal [1]. Gattinoni *et al*. described a biphasic trend of the CoVID-19 pneumonia: in the initial phase – type L pneumonia – elastance is low, as well as recruitability, ventilation/perfusion ratio (V/Q ratio) and lung weight on CT scan. Conversely, in the second phase – type H pneumonia (20–30% of cases) – elastance, recruitability and lung weight are high and right-to-left shunt predominates [4, 5], thus framing in a classical form of ARDS. However, data regarding isolated lung mechanical properties in type L pneumonia are partial and disorganized.

We present preliminary data of a series of patients affected by type L pneumonia. Through the systematic evaluation of transpulmonary pressure, our findings seem to confirm the pseudo-normality of lung mechanics during the first days of mechanical ventilation and in different clinical settings. Even if lungs were severely damaged, the transpulmonary pressures remained below the thresholds commonly referred to as harmful [6], confirming a preserved lung aeration.

Another proof of the pseudo-normality of the respiratory system comes from the calculation of mechanical power [3]. Serpa Neto and coworkers found that risk for ventilation-induced lung injury (VILI) starts to increase from a value above 17 J/min [7]. Despite high ventilatory requests for maintaining acceptable p_aCO_2 and pH, in our series MP_{RS} remained at a borderline value of 17.9 J/min. In an experimental study, Cressoni *et al.* found that VILI occurs with a MP_L above 12 J/min [8]; our data show a median MP_L of 13.1 J/min, that is slightly above the harmful value. Therefore, while standard protective ventilation is unlikely to lead to VILI, we cannot clearly define whether the ventilatory demands in type L pneumonia are injurious to the lung.

Type L pneumonia in characterized by a profound hypoxemia, in most cases dramatically responsive to pronation. Prone positioning involves a redistribution of transpulmonary pressure throughout the lung and an inflation improvement in well perfused dorsal areas, leading to an amelioration of ventilation/perfusion ratio (V/Q ratio) [9]. We evaluated the V/Q ratio through alveolar-to-arterial oxygen gradient (A-aO_2 gradient) and end-tidal CO_2/p_aCO_2 ratio (EtCO_2/p_aCO_2 ratio) [5, 10] both in prone and supine positioning, just before the decubitus change. As expected, pronation entails a reduction of V/Q mismatch (A-aO_2 gradient_{SUP} 419 mmHg; A-aO_2 gradient_{PR} 310 mmHg – P 0.29; EtCO_2/p_aCO_2 ratio_{SUP} 0.6; EtCO_2/p_aCO_2 ratio_{PR} 0.71 – P 0.63); of note, C_{RS} and C_L worsen throughout pronation time (Fig. 1). In previous studies on primary ARDS, prone positioning did not substantially affect C_{RS} nor C_L [9]; although this finding seems to further confirm the peculiarity of CoVID-19 pneumonia with respect to ARDS, its statistical and physio-pathological significance is limited by the small amount of data and a more targeted research is needed.

Conclusion

Our data underline the differences between classical ARDS and type L pneumonia, characterized by a pseudo-normal lung mechanics that deteriorates during prone positioning. Further research is needed to confirm this peculiar trend.

Abbreviations

$A\text{-}aO_2$ gradient: Alveolar-to-arterial Oxygen gradient

ARDS: Acute Respiratory Distress Syndrome

C_{RS}: Respiratory System Compliance

$C_{RS,SUP}$: Respiratory System Compliance, Supine

$C_{RS,PR}$: Respiratory System Compliance, Prone

C_L: Transpulmonary Compliance

$C_{L,SUP}$: Transpulmonary Compliance, Supine

$C_{L,PR}$: Transpulmonary Compliance, Prone

CoVID-19: Coronavirus Infectious Disease-19

CT: Computed Tomography

DP_{RS}: Respiratory System Driving Pressure

DP_L: Transpulmonary Driving Pressure

$EtCO_2/p_aCO_2$ ratio: end-tidal CO_2/p_aCO_2 ratio

ICU: Intensive Care Unit

MP_{RS}: Respiratory System Mechanical Power

MP_L: Transpulmonary Mechanical Power

p_aCO_2: carbon dioxide arterial partial pressure

P_{AW}: Airway Pressure

PBW: Predicted Body Weight

P_{ES}: Esophageal Pressure

P_L: Transpulmonary pressure

RR: Respiratory Rate

V/Q ratio: Ventilation/Perfusion ratio

VILI: Ventilation-Induced Lung Injury

V_t: Tidal Volume

Declarations

- Ethics approval and consent to participate: this study was approved by the Ethical Committee of AUSL Romagna.
- Consent for publication: not applicable.
- Availability of data and materials: the datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.
- Competing interests: the authors declare that they have no competing interests.
- Funding: not applicable.
- Authors' contibutions: LV: study design, data collection, writing of the manuscript; ER: study design, writing of the manuscript; MB: study design, data collection; EG: data collection; AC: data collection; LB: data collection; DPS: data collection; GS: data collection; GB: data collection; LM: data collection; VA: study design, writing of the manuscript. All authors read and approved the final manuscript.
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References

1. Gattinoni L, Coppola S, Cressoni M, Busana M, Rossi S, Chiumello D. COVID-19 Does Not Lead to a "Typical" Acute Respiratory Distress Syndrome. Am J Respir Crit Care Med. 2020 May 15;201(10):1299-1300..
2. Alhazzani W, Møller MH, Arabi YM, Loeb M, Gong MN, Fan E, et al. Surviving Sepsis Campaign: guidelines on the management of critically ill adults with Coronavirus Disease 2019 (COVID-19). Intensive Care Med. 2020 May;46(5):854-887.
3. Gattinoni L, Marini JJ, Collino F, Maiolo G, Rapetti F, Tonetti T, et al. The future of mechanical ventilation: lessons from the present and the past. Crit Care. 2017 Jul 12;21(1):183.

4. Gattinoni L, Chiumello D, Caironi P, Busana M, Romitti F, Brazzi L, et al. COVID-19 pneumonia: different respiratory treatments for different phenotypes? Intensive Care Med. 2020 Apr 14:1–4.
5. Gattinoni L, Chiumello D, Rossi S. COVID-19 pneumonia: ARDS or not? Version 2. Crit Care. 2020 Apr 16;24(1):154.
6. Grieco DL, Chen L, Brochard L. Transpulmonary pressure: importance and limits. Ann Transl Med. 2017 Jul;5(14):285.
7. Serpa Neto A, Deliberato RO, Johnson AEW, Bos LD, Amorim P, Pereira SM, et al. Mechanical power of ventilation is associated with mortality in critically ill patients: an analysis of patients in two observational cohorts. Intensive Care Med. 2018 Nov;44(11):1914-1922.
8. Cressoni M, Gotti M, Chiurazzi C, Massari D, Algieri I, Amini M, et al. Mechanical Power and Development of Ventilator-induced Lung Injury. Anesthesiology. 2016 May;124(5):1100-8.
9. Koulouras V, Papathanakos G, Papathanasiou A, Nakos G. Efficacy of prone position in acute respiratory distress syndrome patients: A pathophysiology-based review. World J Crit Care Med. 2016 May 4;5(2):121-36.
10. Tobin MJ. Basing Respiratory Management of Coronavirus on Physiological Principles. Am J Respir Crit Care Med. 2020. DOI: 10.1164/rccm.202004-1076ED.

Figures

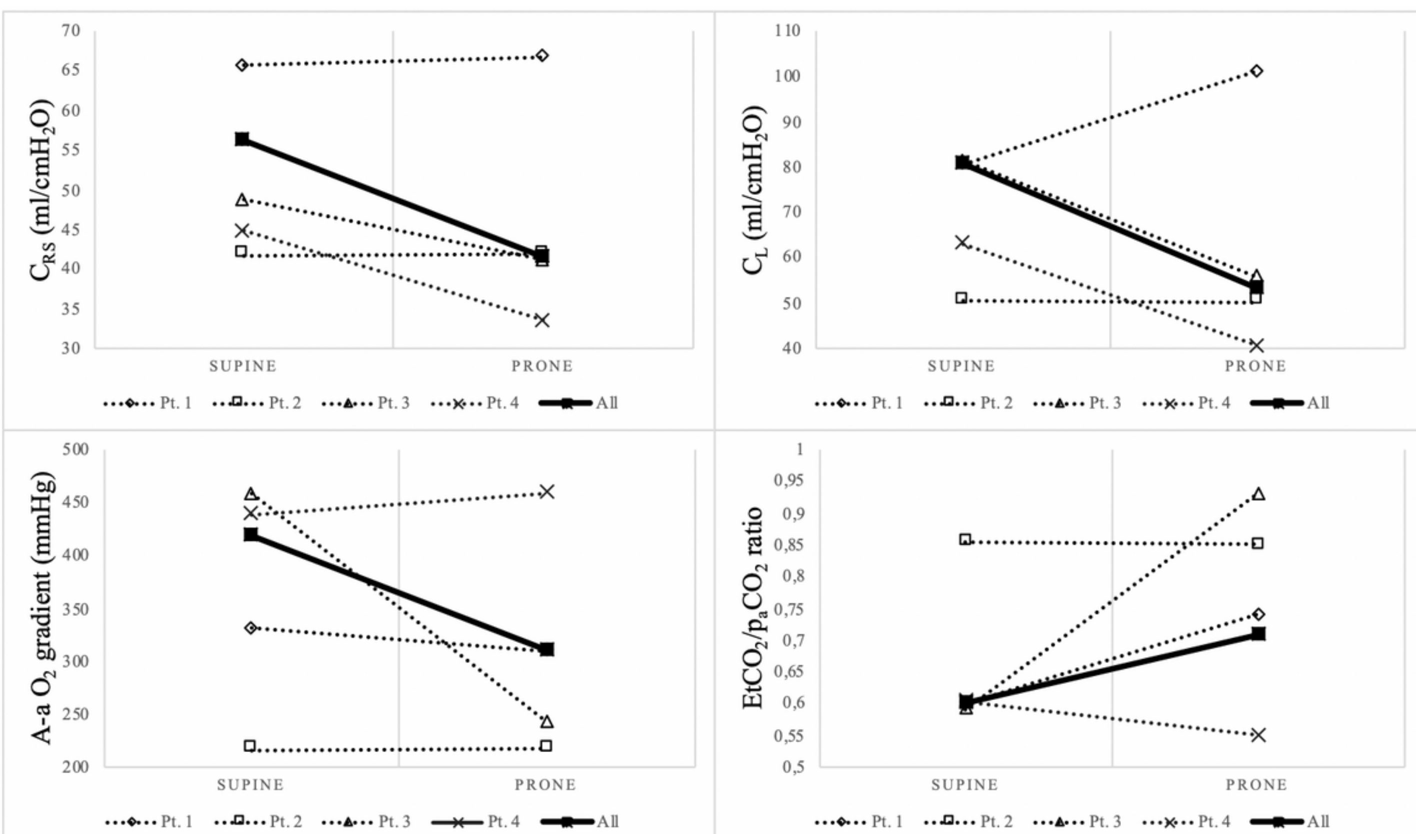

Figure 1

Mechanical and Ventilation/Perfusion ratio variations in supine and prone positioning, just before decubitus change. CRS: Respiratory System Compliance; CL: Transpulmonary Compliance; A-aO2 gradient: alveolar-to-arterial oxygen gradient; EtCO2/paCO2 ratio: end-tidal CO2 to paCO2 ratio.