JSOCMED
JOURNAL OF SOCIETY MEDICINE
Research & Review Articles on Diseases

Journal of Society Medicine
Research & Review Articles on Diseases
Journal of Society Medicine. 2023; 2(10)

Lung Protective Strategy in Acute Respiratory Distress Syndrome with Approach of Compliance and Mechanical Power

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ARTICLE INFO

Article history:
Received
12 September 2023

Revised
10 October 2023

Accepted
31 October 2023

Manuscript ID:
JSOCMED-120923-210-2

Checked for Plagiarism: Yes

Language Editor:
Rebecca

Editor-Chief:
Prof. Aznan Lelo, PhD

ABSTRACT

Introduction: Lung protective strategy was meant to decrese risk of ventilatory induced lung injury without reducing benefit of ventilator. One of the approaches were the use of compliance and mechanical power (MP). Compliance was used to determine how large lung was recruited after ventilatory support. Mechanical power was used to determined enough ventilatory support to that patient.
Case Report: We reported 36 years old female, whom admitted to ICU with diagnosis of acute respiratory distress syndrome caused by community acquired pneumonia. Patient was given pressure controlled ventilation with driving pressure 15cmH2O, positive end expiratory pressure (PEEP) 5 cmH2O, respiratory rate of 20x/min. We used compliance and MP to decide ventilator setting which benefit the patient. At the initial ventilator setting compliance and MP were 15.67 cc/mmHg, and 9.21 joule/min respectedly. The PEEP was increase gradually to 12 cmH2O. Compliance and MP were also increase to 41.67 cc/mmHg and 32.91 joule/min respectedly. Driving pressure was decrease to meet desirable volume tidal 6cc/kg and desirable MP below 22 joule/min. The PEEP was maintained until pneumonia resolved. Patient was extubated in ninth day.
Conclusion: It could be concluded that the use of compliance and MP would help customize ventilatory support the patient need. They would help critical care clinician in making decision to prioritize need of ventilatory support in each individual patient.

Keywords
Mechanical power, Compliance, ARDS

How to cite: Pamugar B, Budipratama D. Lung Protective Strategy in Acute Respiratory Distress Syndrome with Approach of Compliance and Mechanical Power. *Journal of Society Medicine*. 2023; 2(10): 324-329. **DOI: https://doi.org/10.47353/jsocmed.v2i10.96**

INTRODUCTION

Acute respiratory distress syndrome (ARDS) has a high mortality rate in the ICU. ARDS ventilator management uses a lung protective strategy.[1] Lung protective strategy is a strategy to meet the oxygenation needs of patients by minimizing the detrimental effect of mechanical ventilator to ARDS lungs.[2]

The Lung protective strategy provides the maximum limiting value in the management of ARDS. This strategy minimizes the risk of ventilator-induced lung injury (VILI). This limiting value aims to reduce lungs trauma such as barotrauma, volutrauma, and biotrauma. Lung protective strategy cannot objectively assess the condition of the lungs before and after rescue breathing.[2] Compliance and the mechanical power (MP) describes how much pressure / force that ventilator exerts on the lungs. Another benefit compliance and MP can can identify objectively condition of the lungs before and after mechanical ventilator assistance. Compliance and MP can determine the total pressure / force exerted by the ventilator machine on the patient's lungs, which will help the clinician provide adequate ventilator settings needed by the patient.[3]

Case Report

A 36-year-old woman was consulted to the ICU after the second day of stay in the general ward with increasing shortness of breath, accompanied by decreased consciousness and decrease of saturation of 80% with a 15 lpm non-rebreathing mask. The patient was then intubated and given positive pressure ventilation through a bag valve mask. Then, the patient transferred to the ICU.

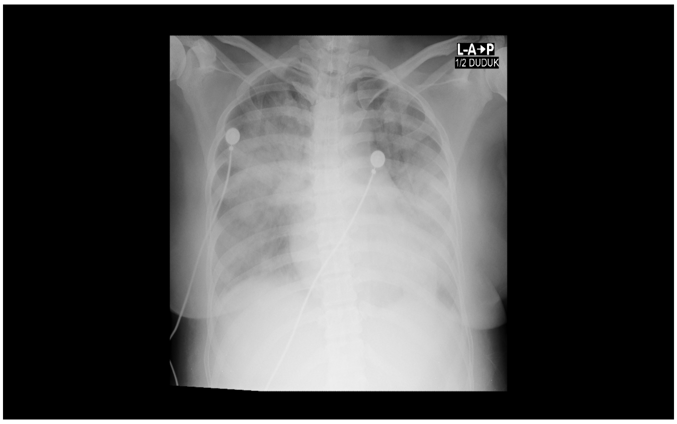

Figure 2: CXR ICU treatment day-0

On physical examination, the patient was not jaundiced. Jugular vein pressure (JVP) was normal. There were coarse ronchi in both lung fields with purulent yellow sputum production, and cold acral with CRT > 3 seconds. Based on diagnostic examinations, we found bilateral opacities based on CRX, leukopenia, thrombocytopenia, increased SGOT and SGPT, and increased D-Dimer. Anti-dengue IgG and IgM examinations showed negative results.

Initial management was one-hour bundle, and ventilator assistance according to the Lung Protective strategy. Initial fluid rescucitation of 30cc/kg was given along with vasopressor to achive target mean arterial pressure (MAP) of ≥ 65mmHg. Blood culture was taken. Broad spectrum of antibiotic of meropenem and levofloxacine was given. Foley catheter, nasogastric tube, and central venous catheter was given to the patient. Paracetamol was given to control body temperature. Nebulizer and intermitten suction through endotracheal tube was given. Analgesia and sedation were given to achieve desire Critical Care Pain Observation Score (CCPOT) and Richmond Agitation and Sedation Scale (RASS). Thromboprophylaxis heparin was given. Gastroprotective proton pump inhibitor was given.

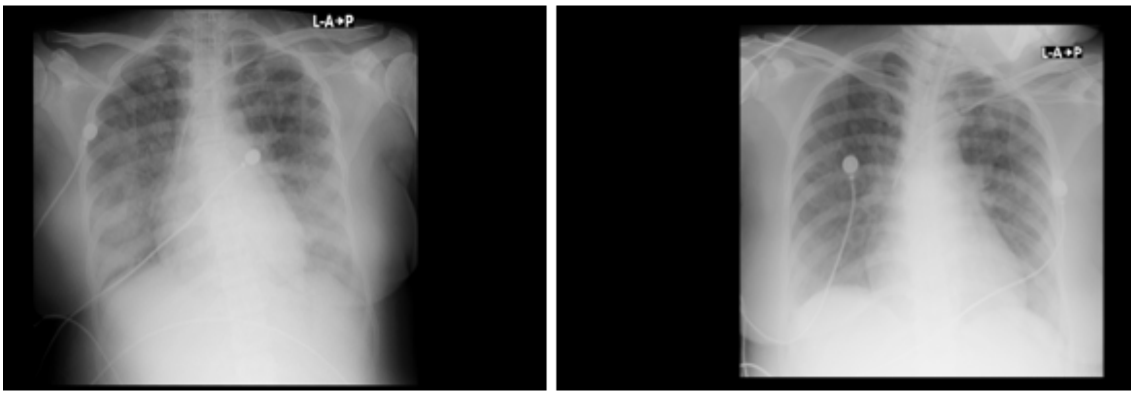

Figure 3: CXR ICU treatment day-1 (left) and treatment day-8 (right)

As the ventilator management the patient was connected to Pressure Controlled Ventilation with 100% oxygen fraction, driving pressure of 15cm H2O, PEEP of 5cmH2O, and respiratory rate of 20x/min with the help of muscle relaxant rocuronium. This initial setting gave tidal volume (TV) of 235cc, 99% saturation with an oxygen fraction of 100%. The compliance and MP were 15.67 cc/mmHg and 9.21 joules/min. The MP increase by increasing the PEEP gradually up to 12cmH2O. Lung compliance increased to 41.67 cc/mmHg, with a tidal volume of 622 ccs and 99% saturation with 100% oxygen fraction. The MP value increased beyond the recommended limit to 32.91 joules/min. Driving pressure was reduced to meet the expected tidal volume of 6cc/kg to 10cmH2O, and the oxygen fraction is lowered to 50%. The tidal volume obtained is 375cc, 99% saturation with 50% oxygen fraction, and MP 16 joules/min. The relaxants were maintained for up to 24 hours. CXR imaging was taken for control.

The patient's condition improves. The patient was sedated, with a pulse rate of 115x/min, blood pressure of 105/59 with norepinephrine 0.1mcg/kg/min, a respiratory rate of 20x/min and 99% saturation. The patient's temperature dropped to 37.2. Diuresis in the first hour 60cc and CRT <3 seconds. The saturation of central venous of oxygen (SCVO2) value was 68%.

Blood culture came out on day 6 in the presence of multi-drug-resistant *S. haemolyticus*, which was sensitive to Doxycycline, Clindamycin, Linezolid, Tetracycline, and Vancomycine. Antibiotics replaced with Doxycycline and Clindamycin via enteral. The patient's condition improves. From clinical signs, mechanical ventilator assistance can be reduced. From diagnostic examination, the P/F ratio increases, indicating improved diffusion and gas exchange. The patient was discharged to general ward in ninth day of ICU.

DISCUSSION

One hour bundle was strategic step-by-step approach proven to increase survival rate in septic shock patients. This bundle comprised of measuring lactate level, obtaining blood culture, administering broad spectrum of antibiotic, and administering fluid resuscitation of 30cc/kg body weight. The purpose of this was to resuscitate and reform oxygen delivery that was initially low after first hit, and to give initial broad spectrum of antibiotics to microorganism causing this condition until definitive microorganism identified. Oxigen delivery was resuscitated if lactate level went down to normal.[4] In this patient every step of one hour bundle was taken measure. Target of macrocirculation was achieved. Value of MAP, CRT, and urine output were achieved. However, biomarker of microcirculation of lactate could not be taken. This was due to limitation of insurance. Alternatively we used SCVO2 to check perfusion after resuscitation.

Compliance value was the ability of lung units to change the incoming volume units. The greater the compliance, the greater the expansion of the lungs for a given pressure value. Conversely, the smaller the compliance, the smaller the lung expansion for the same pressure value. In ARDS patients lung compliance could decrease caused by collapse of many alveoli. This could cause V/Q mismatch. The compliance score is used as a reference for successful management of ARDS patients in the lungs who are recruitable. There were static and dynamic compliance of the lung that can be measured. Static compliance was change in volume of the lungs over change of pressure at given time. Dynamic compliance was change in volume of the lung over change of pressure at multiple time rhythmically follow breathing pattern. Dynamic compliance also taken into measure airway resistance and muscle relaxation. Dynamic compliance was more accurate to describe the 'actual' compliance of the lung, which was elasticity of lung surface. Normal dynamic compliance was 200cc/cmH2O. In reality dynamic compliance need special tools and ventilator to be measured. Static compliance could be alternative way to evaluate elasticity of the lung. The formula for static compliance is:[3]

Cstat = V / (Pplat – PEEP), where:

Cstat: static compliance value

V: volume change

Pplat: plateau pressure

PEEP: positive-end expiratory pressure

The MP value was the energy per unit of time generated by the mechanical ventilator in the respiratory system. The MP value was a combined net value consist of PEEP, driving pressure, and respiratory rate. The value of MP was directly proportional to the incidence of ventilator induced lung injury (VILI). Recommended value of MP was 22 joule/minutes. Incidence of VILI was increase in MP more than 22 joule/minutes. In ARDS patients, the use of MP could determine whether respiratory assist through ventilator was sufficient, less-sufficient, or over. The MP value could also influence the components of PEEP, driving pressure, and respiratory rate which can be decreased or increased. The value of MP was taken from equation of motion. Equation of motion explained pressure needed to deliver air into the lung was influenced by elastic component of the lung (volume and compliance) and resistive components of the lung (flow and airway resistence). This formula was too complex to be measured bedside. Chiumello, in his journal, simplified the formula. However, this formula had to be measured in controlled ventilation. In spontaneous breathing patient, this formula could not be use.[5,6]

MP = (VE x (Peak pressure + PEEP + (inspiratory flow/6))) / 20 for volume-controlled ventilation, and
MP = 0.098 x RR x Vt x (PEEP + driving pressure) for pressure-controlled ventilation, where
MP: mechanical power
VE: minute ventilation
Vt: tidal volume

	ICU D-0				D-1	D-2	D-3	D-4	D-5	D-6	D-7	D-8	D-9
	0 min	30 mir	60 min										
RR actual (x/min)	20	20	20	20	20	14	17	17	18	16	17	20	19
Saturation (%)	99	99	99	99	99	99	99	99	99	99	99	99	99
Mode	PCV	PCV	PCV	PCV	PCV	SIMV	SIMV	PSV	PSV	PSV	PSV	SM 6lpm	BNC 3lpm
RR setting (x/min)	20	20	20	20	20	10	10	0	0	0	0		
Fio2 (%)	100	100	100	100	50	35	35	35	35	35	35		
Vol. Tidal (mL)	235	258	622	375	410	405	398	341	402	458	368		
PEEP (cmH2O)	5	8	12	12	12	12	12	12	12	12	10		
Driving Pressure (cmH2O)	15	15	15	10	10	10	10	10	10	10	6		
Compliance	15.7	17.2	42	38	41	40.5	39.8	38.1	40.2	45.8	61.3	Undetermined	Undetermined
Mechanical Power (joule/min)	9.21	11.6	33	16	17.7	Undetermined	Undetermined	Undetermined	Undetermined	Undetermined	Undetermined	Undetermined	Undetermined

Fig. 4 Patient's mechanical ventilator usage

The patient received initial ventilator assistance with an outcome of compliance of 15.67 and MP of 9.21. Lungs were restricted but possibly recruitable, because of low compliance and minimal MP value. This explained the net pressure of ventilator exerted to surface area of alveoli was not big. The value of MP was maximized by adding PEEP. Tidal volume was increased to 622cc, and lung compliance increased to 41.67. This explained that collapsed alveoli were now open due to PEEP. Increase in tidal volume would also increase MP. The MP increased to 32.91, in which it exceeded the recommended energy threshold. The incidence of VILI was very high if this situation stay. So components other than PEEP could be changed, namely driving pressure. Driving pressure could be decrease to achieve the recommended tidal volume of 6cc/kg body weight. As the tidal volume went down, so did the MP. The MP value went down to 16 joule/minutes. Target MP was achieved (Fig. 4).

The limitation of this management was the limited resource of ventilator and antibiotic. Ventilator could not perform inspiratory hold, so the plateau pressure value is undetermined. The compliance formula in this patient used the peak pressure in exchange of plateu pressure. The compliance value in this patient might be overestimated. However, the value could still describe change of elasticity of the lung even using peak pressure. Compliance of the patient was increase after ventilator management guided with mechanical power.

Second limitation of the patient was limitation of antibiotic. Blood culture grow multidrug resistence streptococcus hemolyticus that only sensitive to intravenous antbiotic linezolid and vancomycin. Due to limitation of insurance policy the antibiotic could not be covered. In exchange we de-escalate using oral antibiotics Doxicycline and Clindamycine which were still sensitive. Although it was not the gold standard, patient condition still improved. Patient could be wean from ventilator, perfusion was adequate, all sign and symptoms of infection was diminished, and patient could then be discharged to general ward in ninth day of ICU.

CONCLUSION

Ventilators were the gold standard for hypoxemia management in ARDS. However, if overused ventilator could increase the risk of VILI. Lung protective strategy help protecting the lung from detrimental effect of ventilator. However, it could not objectively describe the nett force of ventilator exert the lung. Compliance and MP could help determine lung expansion after ventilator management. They could also determine objectively how much nett force of the ventilator is given to the lungs. They could also use in remote ICU because they had simplified formula.

DECLARATIONS

This text is already approved by the Ethics Committee of Hasan Sadikin General Hospital.

CONSENT FOR PUBLICATION

The Authors agree to publication in Journal of Society Medicine.

FUNDING

This research has received no external funding

COMPETING INTERESTS

The authors declare that there is no conflict of interest.

AUTHORS' CONTRIBUTIONS

All authors contribute equally, from the conception, study, execution, analysis and interpretation of the data. Authors agreed to publish this work, and agreed to be accountable for the work.

ACKNOWLEDGMENTS

None

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