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Relation between Mechanical Power and Mortality in Mechanically Ventilated Adult Patients:

A Protocol of Thesis
Submitted For Partial Fulfillment of Master's Degree In Anesthesia, Intensive Care and Pain Management

By

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INTRODUCTION

Critically ill patients with acute respiratory failure frequently require invasive mechanical ventilation to maintain adequate gas exchange. However, mechanical ventilation itself can contribute to lung injury, a phenomenon known as ventilator-induced lung injury (VILI) **(1).**

Ventilator-induced lung injury arises from the complex interaction between the mechanical forces applied by the ventilator and the capacity of the lung parenchyma to tolerate these forces(**2**).

There are many ventilator-related determinants contributing to VILI include airway pressures, tidal volume, inspiratory flow, and respiratory rate **(3).**

Lung susceptibility to ventilator-induced lung injury is influenced not only by ventilator settings but also by intrinsic lung factors such as reduced functional lung size ("baby lung"), parenchymal heterogenicity, and cyclic alveolar collapse and reopening. These mechanisms contribute to barotrauma, volutrauma, atelectotrauma, and biotrauma **(4).**

Lung-protective ventilation strategies such as lower tidal volume (VT), reduced driving pressure (DP), limitation of plateau pressure (Pplt), and appropriate positive end-expiratory pressure (PEEP) have been shown to reduce VILI and improve survival by minimizing mechanical stress on injured lung tissue**(5).**

Mechanical power (MP) represents the total energy delivered from the ventilator to the respiratory system per unit time, integrating tidal volume, airway pressures, inspiratory flow, and respiratory rate. This concept provides a unified

framework for understanding ventilator-induced lung injury, as excessive energy transfer may lead to cellular deformation and inflammatory lung damage. The concept was introduced by **Gattinoni et al.**, and simplified equations now allow bedside estimation of MP in different ventilation modes **(6).**

Driving pressure (ΔP) is a key predictor of outcome in Acute Respiratory Distress Syndrome, reflecting lung stress better than tidal volume alone; however, it is influenced by compliance and PEEP, limiting its use as an independent target (**7**)

Mechanical power integrates ventilatory variables but does not capture regional lung heterogeneity; thus, combining it with individualized monitoring may better reduce ventilator-induced lung injury (**8**).

Recent evidence suggests that lower MP values are associated with improved outcomes in mechanically ventilated patients. Mechanical power below 12 J/min is generally considered to represent a relatively safe range associated with a lower risk of ventilator-induced lung injury. In contrast, values between 12 and 17 J/min have been described as an intermediate-risk zone, where the probability of lung injury and adverse outcomes progressively increases. Mechanical power exceeding 17 J/min has been consistently associated with higher mortality, prolonged mechanical ventilation, and increased incidence of ventilator-induced lung injury in critically ill patients. Therefore, MP has gained attention as a potential bedside tool for optimizing lung-protective ventilation strategies and improving patient outcomes. (**9**).

RATIONALE

Mechanical ventilation is essential for the management of patients with acute respiratory failure, yet it can contribute to ventilator-induced lung injury when excessive mechanical stress is applied to the lungs. Conventional lung-protective strategies focus on controlling individual ventilatory parameters such as tidal volume, plateau pressure, and driving pressure. However, these variables are often evaluated separately, despite the fact that lung injury likely results from the combined mechanical energy delivered to the respiratory system.

Mechanical power has emerged as an integrative parameter that represents the total energy transferred from the ventilator to the lungs per unit time, incorporating tidal volume, airway pressures, inspiratory flow, and respiratory rate. This concept provides a more comprehensive assessment of the mechanical load imposed on lung tissue and may better reflect the risk of ventilator-induced lung injury.

RESEARCH QUESTION

Is there a relation between mechanical Power measured in the first 72 hours of invasive ventilation and 28-day mortality or other clinical outcomes?

HYPOTHESIS

Null hypothesis:

There is no relation between mechanical Power measured in the first 72 hours of invasive ventilation and 28-day mortality or other clinical outcomes.

Alternative hypothesis:

There is a relation between mechanical Power measured in the first 72 hours of invasive ventilation and 28-day mortality or other clinical outcomes.

AIM OF THE WORK

Evaluating the association between mechanical Power measured in the first 72 hours of invasive ventilation and 28-day mortality and other clinical outcome.

OBJECTIVES

- Estimate mechanical power (MP) at 24, 48, and 72 hours after initiation of invasive mechanical ventilation and calculate the 72-hour MP variation rate separetely.
- Compare MP values between survivors and non-survivors at day 28.
- Evaluate the correlation of MP with driving pressure (ΔP) and plateau pressure (Pplat) at the predefined time points.
- Determine the association of MP and its variation with ventilator-free days (VFDs) and ICU length of stay.

PATIENTS & METHODS

I. Technical design:

- **Site of study:** This study will be conducted in Anesthesia intensive care and pain management department, the Surgical Intensive Care Unit, Zagazig University Hospitals after approval of irb.
- **Duration of study:** This study will be carried out within 1 year. **(Singh et al., 2026)**

- **Sample size :**

According to confidence interval two sided 95% power 80% mean MP 137.5± 5.9 of survivor compared to MP 41.74 of non survivor so sample size was calculated 116 patients. **(Singh et al., 2026)**

- **Inclusion criteria:**
    - First degree relative patient acceptance.
    - Age ≥18 years.
    - Sex: both sexes
    - Invasive controlled mechanical ventilation initiated in ICU and expected duration ≥72 h.
    - Enrollment within the first 8 h after initiation of controlled ventilation.

- **Exclusion criteria**:
    - Predominant spontaneous breathing/weaning modes in first 48 h.
    - Severe hemodynamic instability precluding standardized measurements.
    - Pre-ICU prolonged mechanical ventilation before admission.
    - Pregnancy.
    - Chest trauma

- **Withdrawal criteria:**

* The 1st degree relative has the right to withdraw from the study at any time without any negative consequence or harm on their patients' medical treatment plan.

***** Extubation within the first 72 hours of intubation

II. Operational design:

- **Type of the study:** prospective observational Cohort study which will be carried out in Zagazig university hospitals.
- **Parameters of the study :**
- **Upon the ICU admission:** all patients will undergo a standardized evaluation:

♦ **Clinical Assessment:**

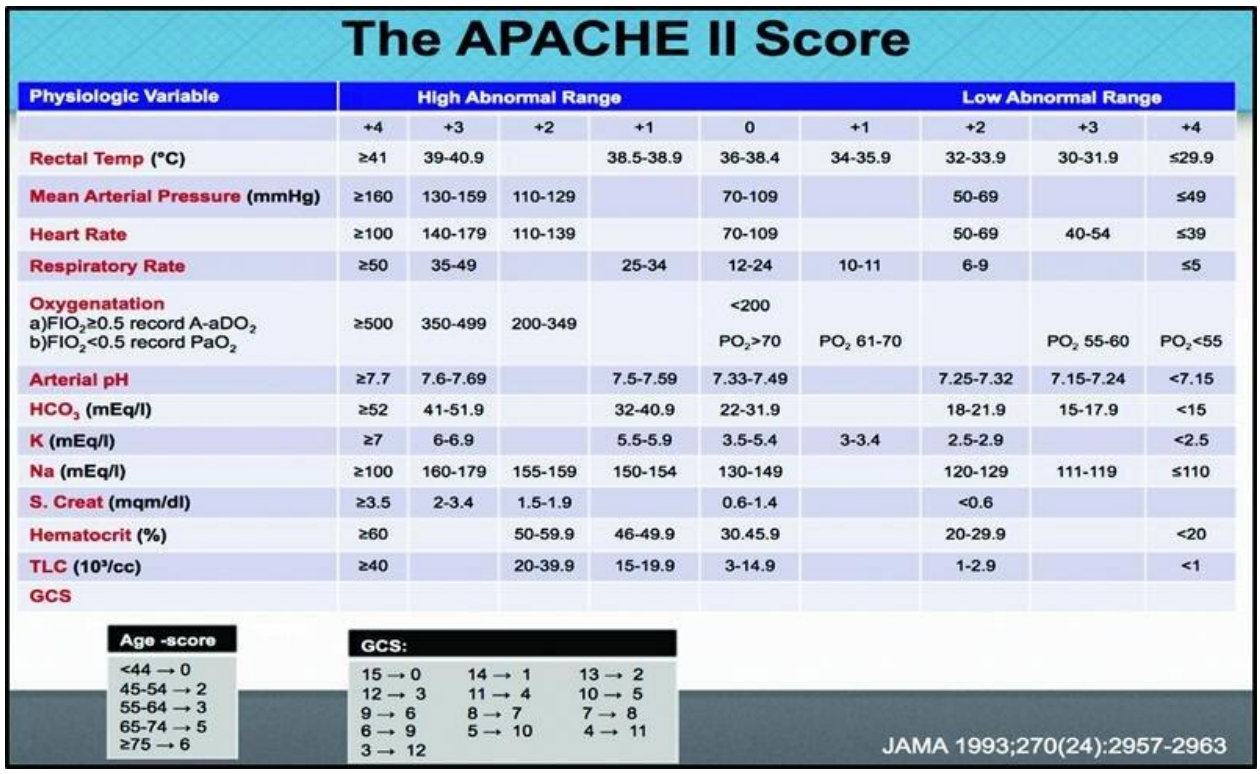
- Comprehensive history: comorbidities, mechanism of illness, prior treatment, medications.
- Physiological monitoring: heart rate, blood pressure , continuous ECG, SpO_2, $EtCO_2$, core temperature.
- Neurological status: Glasgow Coma Scale (GCS).
- Chest assessment: clinical and radiological evaluation for preexisting pulmonary pathology.

♦ **Laboratory Investigations:**

- Complete blood count (CBC)
- Coagulation profile: PT, INR, PTT
- Liver and kidney function tests
- Serum glucose level
- Arterial blood gas (ABG) with PaO_2/FiO_2 ratio

♦ **Severity Scoring:**

- **APACHE II** at baseline for risk stratification **(figure 1)(10).**
- **SOFA** score at baseline and at predefined intervals **(table 1)(11).**



The APACHE II Score

Physiologic Variable	High Abnormal Range						Low Abnormal Range		
	+4	+3	+2	+1	0	+1	+2	+3	+4
Rectal Temp (°C)	≥41	39-40.9		38.5-38.9	36-38.4	34-35.9	32-33.9	30-31.9	≤29.9
Mean Arterial Pressure (mmHg)	≥160	130-159	110-129		70-109		50-69		≤49
Heart Rate	≥100	140-179	110-139		70-109		50-69	40-54	≤39
Respiratory Rate	≥50	35-49		25-34	12-24	10-11	6-9		≤5
Oxygenatation a)FIO_2≥0.5 record A-aDO_2 b)FIO_2<0.5 record PaO_2	≥500	350-499	200-349		<200 PO_2>70	PO_2 61-70		PO_2 55-60	PO_2<55
Arterial pH	≥7.7	7.6-7.69		7.5-7.59	7.33-7.49		7.25-7.32	7.15-7.24	<7.15
HCO_3 (mEq/l)	≥52	41-51.9		32-40.9	22-31.9		18-21.9	15-17.9	<15
K (mEq/l)	≥7	6-6.9		5.5-5.9	3.5-5.4	3-3.4	2.5-2.9		<2.5
Na (mEq/l)	≥100	160-179	155-159	150-154	130-149		120-129	111-119	≤110
S. Creat (mqm/dl)	≥3.5	2-3.4	1.5-1.9		0.6-1.4		<0.6		
Hematocrit (%)	≥60		50-59.9	46-49.9	30.45.9		20-29.9		<20
TLC (10^3/cc)	≥40		20-39.9	15-19.9	3-14.9		1-2.9		<1
GCS									

Age -score

<44 → 0
45-54 → 2
55-64 → 3
65-74 → 5
≥75 → 6

GCS:

15 → 0 | 14 → 1 | 13 → 2
12 → 3 | 11 → 4 | 10 → 5
9 → 6 | 8 → 7 | 7 → 8
6 → 9 | 5 → 10 | 4 → 11
3 → 12

JAMA 1993;270(24):2957-2963

Figure 1: The APACHE II score

Table 1: Modified Sequential Organ Failure Assessment (SOFA) Score

Organ System	0	1	2	3	4
Respiratory SpO2/FiO2	>400	≤400	≤315	≤235	≤150
Liver	No scleral icterus or jaundice			Scleral icterus or jaundice	
Cardiovascular, hypotension	No hypotension	MAP <70 mm Hg	dopamine≤5 or dobutamine any dose	dopamine>5 epinephrine≤0.1 norepinephrine≤0.1	dopamine>15 epinephrine>0.1 norepinephrine>0.1
CNS, Glasgow Coma Score	15	13–14	10–12	6–9	<6
Renal, Creatinine mg/dL	<1.2	1.2–1.9	2.0–3.4	3.5–4.9	>5.0

♦ Standard ICU Care

All patients will receive standardized supportive care, including:

- Airway management, oxygenation, and ventilator optimization by protective lung strategy where tidal volume 6-8ml/kg, PEEP=5-8 cmH2O, pressure support 8-12 cmH2O, Fio2 starts with 100%then decrease till optimization to least Fio2=40%Respiratory rate 15-20 breath per minute
- Hemodynamic support with fluids and vasopressors as indicated.
- Routine neurological monitoring.
- Maintenance of normothermia, electrolyte and glucose balance.
- Early enteral nutrition.
- Standard prophylaxis: DVT, stress-ulcer, infection prevention bundles.
- Sedation, pain control, skin care, and patient repositioning per ICU protocol.

- **Mechanical Power Measurement**

Ventilator parameters will be recorded every 8 hours for the first 72 hours. Mechanical power (MP) will be calculated as :

- **VCV (Piriyapatsom et al.) (12):**

$$\mathbf{MP=0.098\times VT\times RR\times(PIP-\frac{1}{2}\Delta P)}$$

Where

RR = respiratory rate, VT= tidal volume,

PIP is peak inspiratory pressure in cmH_2O

ΔP is modified driving pressure in cmH_2O, which equals to peak inspiratory pressure minus PEEP

MP values will be averaged at 24, 48, and 72 hours. The 24-hour and 72-hour MP variation rate (%) will be calculated as:

MP variation rate in first 24 hour = (Baseline MP - MP at 24h) / Baseline MP × 100

MP variation rate in 72-hour = (Baseline MP - MP at 72h) / Baseline MP × 100

Baseline MP is after first 8 hour of initiation of mechanical ventillation

DATA COLLECTION

For each patient the following data will be collected :

***Patient Characteristics**

- **Demographics:** Age, sex, BMI, ASA, cause of admission
- **Indications for mechanical ventilation:** Hypoxic respiratory failure, encephalopathy
- **Primary organ failure:** Lung, liver, kidney
- **ARDS severity:** No, mild, moderate, severe
- **Severity-of-illness scoring:**
    - APACHE II and SOFA scores at admission
    - Follow-up SOFA at 24, 48, and 72 hours

*** Laboratory and Physiological Parameters**

- PaO_2/FiO_2 ratio
- Routine labs and ABG for metabolic/organ status

*** Ventilator Parameters and Mechanical Power (MP)**

- **Ventilation mode:** Volume-controlled ventilation (VCV)
- **Mechanical power (MP):** Calculated at 24 h, 48 h, and 72 h
- **MP variation rate (%) :** Calculated at 24 h and 72 h
- **Correlation of MP with ventilator parameters:** Driving pressure (ΔP) and plateau pressure (Pplt) at 24 h, 48 h, and 72 h

*** Clinical Interventions and Supportive Measures**

- Vasopressor requirement (none, single, dual)
- Prone positioning
- Tracheostomy

*** Outcomes and Follow-Up**

- 28-day mortality
- Ventilator-free days (VFDs)
- ICU length of stay

OUTCOME

- **The primary outcome:**

- To explore the correlation between mechanical power over first 72 hours and 28-day mortality rate

- **The secondary outcomes**:

- 1. Correlation of mechanical power (MP) with driving pressure (ΔP) and plateau pressure (Pplat) at 24, 48, and 72 hours after initiation of mechanical ventilation.
- 2. Calculation of Ventilator-free days (VFDs) within the first 28 days.
- 3. Calculation of Length of stay (LOS) in the intensive care unit (ICU)

III. ADMINISTRATIVE DESIGN:

A. Approval will be obtained from the scientific committee of anesthesiology department.

B. Approval will be obtained from the institutional review board (IRB) of faculty of medicine Zagazig University.

C. A written informed consent will be signed from all first degree relatives after discussing the study design including procedure, drugs, and possible adverse effects.

RESULTS

Collected data will be presented in tables and suitable graphs and analyzed by (SPSS) statistical package for the social sciences program using appropriate statistical methods.

DISCUSSION

Discussion will be done on results compared to related literature and scientific research to explain the reasons for getting such results.

CONCLUSION AND RECOMMENDATIONS

Conclusions and recommendations will be derived from the findings of the study.

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