A 5-year registry of mechanically ventilated patients comprising epidemiology, initial settings, and clinical outcome

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Introduction
Our primary aim was to document our interactions with patients subjected to mechanical ventilation (MV) in the Critical Care Department focusing on epidemiological characteristics; the initial modes of ventilation used, and initial settings. Our secondary aim was to document final clinical outcomes of MV, including length of stay, weaning, complications, and hospital mortality.

Patients and methods
Patients' data were collected retrospectively from January 2010 to December 2014 (5 years) through reviewing an electronic database (Medica Plus).

Results
We enrolled a total of 1081 patients. The duration of ventilation was 6±10 days, and length of ICU stay was 13±15 days. The predominant indications of ventilation were cardiac diseases followed by respiratory diseases, neurological diseases, sepsis, and septic shock. Volume controlled ventilation was the most common initial mode of ventilation followed by Non Invasive Continuous Positive Airway Pressure – Pressure Support (NICPAP-PS) and pressure controlled ventilation. Noninvasive ventilation was associated with shorter duration on MV and ICU stay. Pressure Support – Continuous Positive Airway Pressure (PS-CPAP) was the most common weaning mode used followed by unplanned extubation, Non Invasive Continuous Positive Airway Pressure (NICPAP), T-piece, and synchronized intermittent mandatory ventilation. Highest rate of successful weaning was in patients with central nervous system diseases followed by respiratory diseases, cardiac diseases, and least in patients with sepsis and septic shock. Mortality rate in mechanically ventilated patients was 64%. Mortality rate was higher in patients with cardiac diseases followed by respiratory diseases, central nervous system diseases, and septic shock. Mortality was higher with higher levels of tidal volumes, higher FiO2 levels, and lower positive end-expiratory pressure levels. Mortality was higher in invasive ventilation than noninvasive ventilation. Patients with failed weaning had higher mortality.

Conclusions
We have demonstrated the magnitude of MV use in our ICU, the epidemiology and initial ventilation modes used, and their association with complications and inhospital mortality.

Keywords:
epidemiology, mechanical ventilation, mortality, settings, weaning

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to December 2014 (5 years). A total of 1081 critically ill patients were included in our study, and our ICU is a mixed medical, surgical, and coronary care unit. The study has been approved by the ethics committee of Cairo University and has therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. All patients’ next of kin or legal guardians signed an informed consent to participate in this study on human participants and to publish and report the participating patient’s data in any form.

(1) Patients data were retrieved through reviewing written paper and electronic database, that is patients’ files and records, and reviewing the electronic health record database (medica plus).

Inclusion criteria
All patients who were receiving invasive MV for at least 12 h or noninvasive positive-pressure ventilation (NPPV) for at least 1 h were included in this study.

Exclusion criteria
The exclusion criteria included incomplete medical records.

Methods of study
A retrospective cohort study was conducted, and the data collection focused on the following: age, sex, comorbidities: hypertension, diabetes mellitus, anemia, smoking, malignancy, dyslipidemia, sepsis, and vascular, gastrointestinal tract, liver, neurological, renal, gynecological, endocrinical, rheumatological, polytrauma, cardiac, and respiratory diseases.

(1) Initial reason for MV [cardiac, respiratory, sepsis and septic shock, and central nervous system (CNS)].
(2) Initial mode of ventilation recorded on first day of MV.
(3) Initial ventilator settings recorded on first day of ventilation [tidal volume (Vt), respiratory rate (RR), fraction of inspired oxygen (FiO2), and positive end-expiratory pressure (PEEP)].

Outcome
(1) Weaning success is defined as nonassisted breathing for 48 h after extubation. Weaning failure is defined as either the failure of spontaneous breathing trial (SBT) or the need for reintubation within 48 h following extubation. Difficult weaning is defined as the need for more than three SBTs or more than 1 week to achieve successful weaning [1].

(2) Complications: cardiopulmonary arrest, pneumothorax, tracheo-esophageal fistula, and ventilator-associated pneumonia (VAP), defined as pneumonia that occurs 48–72 h or thereafter following endotracheal intubation, characterized by the presence of a new or progressive infiltrate, signs of systemic infection (fever and altered white blood cell count), changes in sputum characteristics, and detection of a causative agent [2].
(3) Duration of ventilation, ICU length of stay, and 30-day hospital mortality.

Statistical analysis
Data were collected, revised, coded, and entered to the Statistical Package for Social Science (IBM SPSS, UK), version 20 for analysis and included the following:

Qualitative data were presented as number and percentages whereas quantitative data were presented as mean, SDs, and ranges for the parametric data and median with interquartile ranges (IQR) for the nonparametric data.

The comparison between two groups with qualitative data was done by using $\chi^2$-test, and Fisher’s exact test was used instead of $\chi^2$-test when the expected count in any cell was found less than 5.

The comparison between two independent groups with quantitative data and parametric distribution was done by using independent $t$-test whereas the comparison between more than two groups with quantitative data and parametric distribution was done by using one-way analysis of variance test.

Logistic regression analysis was used to assess the significant predictors of mortality with odds ratio (OR) and 95% confidence interval (CI).

The confidence interval was set to 95%, and the margin of error accepted was set to 5%. So, the $P$ value was considered significant as follows: $P>0.05$: nonsignificant, $P<0.05$: significant, and $P<0.01$: highly significant.

Results
Our retrospective cohort study involved 1081 patients admitted to the Critical Care Department (Cairo University) and connected to MV in the period from January 2010 to December 2014.

Data were obtained from department database (Medica plus 4).
Demographic data
In our study, the median age of patients was 55 (IQR: 36–74) years, and they were classified into three main groups according to age (Fig. 1): young age (≤30 years) group had 176 (16.3%) patients, middle age (31–60 years) group had 402 (37.1%) patients, and old age (>60 years) group had 503 (46.5%) patients. Sex distribution was 565 (53%) female and 511 (47%) male patients (P=0.001).

Comorbidities and causes of ventilation
Age groups and cause of mechanical ventilation
Cardiac causes were the most common among patients aged 60–70 years (24.2%), respiratory causes were the most common among patients aged 70–80 (24.3%) years, sepsis and septic shock were the most common among patients aged 50–60 years (19.6%), and CNS causes of ventilation were the most common among patients aged 20–30 years (23.5%) (P=0.0001) (Table 1 and Fig. 2).

Sex and cause of ventilation
There was no significant association between the sex of the patient and cause of ventilation (P=0.194).

Modes of mechanical ventilation
Different modes of MV were used in our ICU and frequency of each mode is as follows: the most common mode of MV in the total number of patients was volume controlled ventilation (VCV) (61.8%) followed by Non Invasive Continuous Positive Airway Pressure (NICPAP) (15.4%), positive crankcase ventilation (PCV) (14.7%), Pressure Support – Continuous Positive Airway Pressure (PS–CPAP) (8%), and bilevel positive airway pressure (0.1%) (Fig. 3).

Mode of ventilation and causes of ventilation
VCV mode was most common in cardiac diseases (48.4%) followed by respiratory diseases (21.7%), CNS diseases (16.3%), and sepsis and septic shock (13.6%).

Table 1 Comorbidities and causes of ventilation

<table>
<thead>
<tr>
<th>Comorbidities</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypertension</td>
<td>454 (42)</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>389 (36)</td>
</tr>
<tr>
<td>Anemia</td>
<td>54 (5)</td>
</tr>
<tr>
<td>Smoking</td>
<td>151 (14)</td>
</tr>
<tr>
<td>Malignancy</td>
<td>97 (9)</td>
</tr>
<tr>
<td>Dyslipidemia</td>
<td>32 (3)</td>
</tr>
<tr>
<td>Sepsis</td>
<td>151 (14)</td>
</tr>
<tr>
<td>Vascular disease</td>
<td>86 (8)</td>
</tr>
<tr>
<td>GIT disease</td>
<td>54 (5)</td>
</tr>
<tr>
<td>Liver disease</td>
<td>75 (7)</td>
</tr>
<tr>
<td>Neurological disease</td>
<td>292 (27)</td>
</tr>
<tr>
<td>Renal disease</td>
<td>313 (29)</td>
</tr>
<tr>
<td>Gynecological disease</td>
<td>86 (8)</td>
</tr>
<tr>
<td>Endocrinial disease</td>
<td>43 (4)</td>
</tr>
<tr>
<td>Rheumatological disease</td>
<td>54 (5)</td>
</tr>
<tr>
<td>Polytrauma patients</td>
<td>54 (5)</td>
</tr>
<tr>
<td>Cardiac diseases</td>
<td></td>
</tr>
<tr>
<td>Ischemic heart disease</td>
<td>129 (12)</td>
</tr>
<tr>
<td>Acute myocardial infarction</td>
<td>140 (13)</td>
</tr>
<tr>
<td>Ischemic cardiomyopathy</td>
<td>151 (14)</td>
</tr>
<tr>
<td>Unstable angina</td>
<td>86 (8)</td>
</tr>
<tr>
<td>Congestive heart failure</td>
<td>119 (11)</td>
</tr>
<tr>
<td>Arrhythmia</td>
<td>302 (28)</td>
</tr>
<tr>
<td>Infective endocarditis</td>
<td>11 (1)</td>
</tr>
<tr>
<td>Rheumatic heart disease</td>
<td>54 (5)</td>
</tr>
<tr>
<td>Cardiogenic shock</td>
<td>173 (16)</td>
</tr>
<tr>
<td>Pulmonary edema</td>
<td>184 (17)</td>
</tr>
<tr>
<td>Respiratory problems</td>
<td></td>
</tr>
<tr>
<td>Chest infection</td>
<td>356 (33)</td>
</tr>
<tr>
<td>COPD</td>
<td>43 (4)</td>
</tr>
<tr>
<td>Asthmasmics</td>
<td>65 (6)</td>
</tr>
<tr>
<td>Acute respiratory failure</td>
<td>108 (10)</td>
</tr>
<tr>
<td>Pulmonary embolism</td>
<td>21 (2)</td>
</tr>
<tr>
<td>ARDS</td>
<td>32 (3)</td>
</tr>
<tr>
<td>Cause of ventilation</td>
<td></td>
</tr>
<tr>
<td>1081 (100)</td>
<td></td>
</tr>
<tr>
<td>Cardiac causes</td>
<td>451 (41.7)</td>
</tr>
<tr>
<td>Pulmonary edema</td>
<td>169 (15.6)</td>
</tr>
<tr>
<td>Cardiac arrest</td>
<td>57 (5.3)</td>
</tr>
<tr>
<td>Cardiogenic shock</td>
<td>167 (15.4)</td>
</tr>
<tr>
<td>Hypovolemic shock</td>
<td>45 (4.2)</td>
</tr>
<tr>
<td>Pulmonary embolism</td>
<td>13 (1.2)</td>
</tr>
<tr>
<td>Respiratory causes</td>
<td>388 (35.8)</td>
</tr>
<tr>
<td>Chest infection</td>
<td>60 (5.5)</td>
</tr>
<tr>
<td>Acute exacerbation of COPD</td>
<td>212 (19.6)</td>
</tr>
<tr>
<td>Respiratory failure</td>
<td>43 (4)</td>
</tr>
<tr>
<td>Aspiration pneumonia</td>
<td>58 (5.4)</td>
</tr>
<tr>
<td>Hypoxic arrest</td>
<td>10 (0.9)</td>
</tr>
<tr>
<td>Fial chest</td>
<td>1 (0.1)</td>
</tr>
<tr>
<td>ARDS</td>
<td>8 (0.7)</td>
</tr>
<tr>
<td>Sepsis and septic shock</td>
<td>102 (9.4)</td>
</tr>
<tr>
<td>CNS causes</td>
<td>182 (16.9)</td>
</tr>
<tr>
<td>Coma</td>
<td>107 (9.9)</td>
</tr>
<tr>
<td>Convulsions</td>
<td>19 (1.8)</td>
</tr>
<tr>
<td>Postoperative delayed recovery</td>
<td>56 (5.2)</td>
</tr>
</tbody>
</table>

ARDS, acute respiratory distress syndrome; CNS, central nervous system; COPD, chronic obstructive pulmonary disease; GIT, gastrointestinal tract.
PCV mode was most common in respiratory diseases (75.5%) followed by CNS diseases (15.7%), cardiac diseases (5.7%), and sepsis and septic shock (3.1%).

PS-CPAP mode was most common in CNS diseases (54.7%) followed by respiratory diseases (23.3%), cardiac diseases (16.3%), and sepsis and septic shock (5.8%). \((P=0.0001)\)

NICPAP mode was most commonly used in cardiac diseases (62.3%) followed by respiratory diseases (35.9%), CNS diseases (1.2%), and least in sepsis and septic shock (0.6%).

**Ventilator settings**

**Ventilator settings and causes of ventilation**

The highest PEEP (mean: 5.15±1.82 cmH20) was recorded in patients ventilated for respiratory problems, followed by CNS diseases (4.46±1.09 cmH20), cardiac diseases (4.14±1.24 cmH20), and lowest (3.53±1.24) in patients with sepsis and septic shock \((P=0.0001)\) (Table 2).

Tidal volume was highest in patients ventilated for cardiac diseases (447.2±72.9 ml) followed by sepsis and septic shock (447±66.4 ml), respiratory causes (438±77.9 ml), and CNS causes (416.9±88.4 ml) \((P=0.003)\).

Pressure support was highest in patients with cardiac diseases (16.58±1.18 cmH20) followed by sepsis and septic shock (16.36±1.09 cmH20), respiratory (16.2±1.8 cmH20), and CNS (15.9±1.45 cmH20) \((P=0.0001)\).

Respiratory rate was highest in respiratory diseases (16.05±1.97) followed by sepsis and septic shock

<table>
<thead>
<tr>
<th>Organisms</th>
<th>N</th>
<th>% of patients</th>
<th>% of cultures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proteus spp.</td>
<td>23</td>
<td>15.2</td>
<td>2.5</td>
</tr>
<tr>
<td>Pseudomonas aeruginosa</td>
<td>7</td>
<td>4.6</td>
<td>0.8</td>
</tr>
<tr>
<td>Klebsiella pneumoniae</td>
<td>29</td>
<td>19.2</td>
<td>3.2</td>
</tr>
<tr>
<td>Acinetobacter baumannii</td>
<td>45</td>
<td>29.8</td>
<td>5</td>
</tr>
<tr>
<td>MRSA</td>
<td>16</td>
<td>10.6</td>
<td>1.8</td>
</tr>
<tr>
<td>Enterobacter aerogenes</td>
<td>7</td>
<td>4.6</td>
<td>0.8</td>
</tr>
<tr>
<td>Candida spp.</td>
<td>9</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Others</td>
<td>43</td>
<td>28.4</td>
<td>4.8</td>
</tr>
</tbody>
</table>

MRSA, methicillin-resistant Staphylococcus aureus.

PCV mode was most common in respiratory diseases (75.5%) followed by CNS diseases (15.7%), cardiac diseases (5.7%), and sepsis and septic shock (3.1%).
FiO2 was highest in sepsis and septic shock (54.70±8.52) followed by respiratory diseases (54.49±12.39), cardiac diseases (53.30±9.40), and CNS diseases (50.76±10.24) \((P=0.001)\).

**Weaning**

Of 1081 patients who were connected to MV, 401 (37.1%) patients were weaned off, of which 276 (68.8%) patients were successfully weaned and 125 (31.2%) patients failed to be weaned off MV. Different modes of weaning were used and are shown in Table 3 and Fig. 4.

**Weaning and age**

There was no significant association between age of the patient and weaning off MV \((P=0.094)\).

**Weaning and sex**

There was no significant association between sex of the patient and weaning off MV \((P=0.414)\).

**Weaning and the cause of ventilation**

There was significant association between weaning and cause of ventilation, with the highest weaning rates among patients ventilated for CNS (55%) followed by respiratory diseases (43%) cardiac causes (25%), and least in patients with sepsis and septic shock (20%) \((P=0.0001)\) (Fig. 5).

**Comorbidities and weaning**

There was no significant association between the number of comorbidities and weaning off MV \((P=0.312)\).

**Prolonged ventilation**

Overall, 76.6% of patients were put on mechanical ventilation for less than 1 week, 11.6% ventilated for 2 weeks, 5.1% for 3 weeks, and 6.8% for more than 3 weeks, as shown in Table 4.

**Prolonged ventilation and sex**

There was no significant association between sex of the patients and failed weaning and prolonged ventilation \((P=0.804)\).

**Prolonged ventilation and age**

There was no significant association between age of the patients and failed weaning and prolonged ventilation \((P=0.270)\).

**Prolonged ventilation and causes of mechanical ventilation**

Overall, 89.1% of patients with cardiac diseases stayed for less than a week on mechanical ventilation, 5.8% stayed for 2 weeks, 3.1% stayed for 3 weeks, and 2% stayed for more than 3 weeks. In all, 57.7% of patients with respiratory diseases were ventilated for less than a week, 18.8% stayed on mechanical ventilation for 2 weeks, 8.7% stayed 3 weeks, and 14.8% ventilated for more than 3 weeks. Overall, 84.3% of patients ventilated for sepsis and septic shock stayed on mechanical ventilation for less than a week, 10.2% stayed for 2 weeks, 3.1% stayed for 3 weeks, and 2% stayed for more than 3 weeks.

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**Table 3 Days of ventilation and prolonged ventilation**

<table>
<thead>
<tr>
<th>Days on mechanical ventilation</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1–7</td>
<td>828 (76.6)</td>
</tr>
<tr>
<td>8–14</td>
<td>125 (11.6)</td>
</tr>
<tr>
<td>15–21</td>
<td>55 (5.1)</td>
</tr>
<tr>
<td>&gt;21</td>
<td>73 (6.8)</td>
</tr>
</tbody>
</table>

**Figure 4**

Weaning modes. SIMV, synchronized intermittent mandatory ventilation.

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**Table 4 Mortality and tidal volume, mortality and positive end-expiratory pressure**

<table>
<thead>
<tr>
<th>Ventilator setting</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tidal volume</td>
<td>150.00</td>
<td>600.00</td>
<td>440.2840</td>
<td>76.59332</td>
</tr>
<tr>
<td>Pressure support</td>
<td>10.00</td>
<td>25.00</td>
<td>16.3302</td>
<td>1.46664</td>
</tr>
<tr>
<td>PEEP</td>
<td>0.00</td>
<td>22.00</td>
<td>4.4662</td>
<td>1.52844</td>
</tr>
<tr>
<td>Respiratory rate</td>
<td>12.00</td>
<td>30.00</td>
<td>15.5157</td>
<td>1.53665</td>
</tr>
<tr>
<td>FiO2</td>
<td>35.00</td>
<td>100.00</td>
<td>53.3858</td>
<td>10.58074</td>
</tr>
</tbody>
</table>

PEEP, positive end-expiratory pressure.

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**Figure 5**

Weaning according to the cause of ventilation.
mechanical ventilation for less than a week, 6.9% stayed for 2 weeks, 5.9% stayed for 3 weeks, and 2.9% stayed for more than 3 weeks. Overall, 77% of patients with CNS disorders ventilated for less than a week, 14.8% ventilated for 2 weeks, 2.7% for 3 weeks, and 5.5% ventilated for more than 3 weeks \( (P=0.0001) \).

**Prolonged ventilation and mortality**
Mortality rate was 60.4% in patients ventilated for less than a week, 79.2% in patients who stayed for 2 weeks on mechanical ventilation, 81.8% for patients ventilated for 3 weeks, and 71.2% for patients who stayed on mechanical ventilation for more than 3 weeks \( (P=0.0001) \).

**Complications**
Many complications from mechanical ventilation were found in our study group:

1. **VAP**: 160 (14.8%) patients developed VAP.
2. **Barotrauma**: 66 (6.1%) patients developed pneumothorax, of which 11 cases developed tension pneumothorax.
3. **Cardiopulmonary arrest**: 30 (2.8%) cases had arrested on tubal obstruction.
4. **Tracheo-esophageal fistula**: one (0.1%) case was reported to develop fistula.
5. **Tracheotomy**: was done in 76 (7%) patients.

**Ventilator-associated pneumonia**
The most common organism of VAP documented in our patients was *Acinetobacter baumannii* in 45 (29.8%) cases, followed by *Klebsiella pneumoniae* in 29 (19.2%) cases and *Proteus* in 23 (15.2%) cases, as shown in Table 5.

**Successful versus failed weaning and complications**
Patients with failed weaning had higher incidence of cardiopulmonary arrest than successfully weaned patients (2.5 vs. 1.7%) \( (P=0.015) \).

VAP was more common in patients with failed weaning than successfully weaned patients (18 vs. 12.5%) \( (P=0.0001) \).

**Tidal volume and mortality**
It was found that the cutoff value for Vt was 475 \( (7.9 \text{ ml/kg}) \) [mean ideal body weight (IBW): \( \approx 60 \text{ kg} \)] with specificity of 78% and sensitivity of 60%, and higher tidal volume values are associated with mortality and complications \( (P=0.0001) \) (Fig. 6 and Table 6).

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**Table 5 Modes of weaning**

<table>
<thead>
<tr>
<th>Modes of weaning</th>
<th>Frequency n [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>PS-CPAP</td>
<td>283 (70.5)</td>
</tr>
<tr>
<td>SIMV</td>
<td>2 (0.4)</td>
</tr>
<tr>
<td>NICPAP</td>
<td>11 (2.7)</td>
</tr>
<tr>
<td>T-piece</td>
<td>11 (2.7)</td>
</tr>
<tr>
<td>Unplanned extubation</td>
<td>92 (22.9)</td>
</tr>
</tbody>
</table>

SIMV, synchronized intermittent mandatory ventilation; NICPAP, non invasive continuous positive airway pressure; PS-CPAP, pressure support – continuous positive airway pressure.

**Table 6 Area under the curve, sensitivity and specificity of tidal volume, and positive end-expiratory pressure**

<table>
<thead>
<tr>
<th></th>
<th>AUC</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tidal volume</td>
<td>475.0</td>
<td>0.60</td>
<td>0.780</td>
</tr>
<tr>
<td>PEEP</td>
<td>9.0000</td>
<td>0.987</td>
<td>0.990</td>
</tr>
</tbody>
</table>

AUC, area under the curve; PEEP, positive end-expiratory pressure.
PEEP and outcome
It was found that the cutoff value for PEEP was 9 with specificity 99% and sensitivity 98%, and higher PEEP levels were associated with mortality and complications ($P=0.0001$) (Fig. 7 and Table 6).

In-hospital mortality
In-hospital mortality among mechanically ventilated patients occurred in 696 (64.4%) patients.

There was no significant association between age and mortality ($P=0.66$). There was no significant association between sex and mortality ($P=0.643$).

Comorbidities and mortality
There was a significant association between mortality and comorbidities, as highest mortality was seen in patients with six (76.4%) comorbidities and lowest in patients with only two (47.7%) comorbidities ($P=0.0001$).

Cause of ventilation and mortality
Mortality was significantly higher in patients ventilated because of cardiac diseases (41.8%) followed by respiratory disease (31.8%) and CNS diseases (13.8%) and lowest in patients with sepsis and septic shock (12.6%) ($P=0.0001$) (Fig. 8).

Ventilator settings and mortality
Nonsurvivors had higher significant difference of $V_t$ than survivors (444.32±73.81 vs. 426.33±84.32) ($P=0.019$).

Survivors had significantly higher PEEP than nonsurvivors (7.74±1.26 vs. 4.32±1.64) ($P=0.0001$).

$FiO_2$ was significantly higher in nonsurvivors than survivors (54.97±10.39 vs. 50.5±10.31) ($P=0.0001$).

However, no significant difference was found between survivors and nonsurvivors in pressure support and respiratory rate ($P=0.937$ and 0.969).

Invasive versus noninvasive ventilation and mortality
There was a significantly lower percentage of mortality in patients with noninvasive ventilation (NIV) (28.9%) compared with patients with invasive modes (72.2%) ($P=0.0001$).

Weaning and in-hospital mortality
In all, 61% of successfully weaned patients survived to hospital discharge in comparison with only 20.6% survived (79.4%) in nonweaned patients ($P=0.0001$).
Successful versus failed weaning and mortality
Patients with failed weaning had higher mortality than successfully weaned patients (24.4 vs. 14.5%).

ICU length of stay and duration of ventilation
Length of stay (LOS) of the mechanically ventilated patient in our study was 13.28±15.25 days, with median of 8 days, whereas duration of mechanical ventilation was 6.70±10.98 days, with median 3 days.

Cause of ventilation, duration of ventilation, and length of stay
Patients with respiratory diseases as a cause of ventilation had significant longer duration of ventilation (11.3±15.7 days) followed by CNS diseases (5.95±7.38 days), sepsis and septic shock (5.14±6.03 days), and cardiac diseases (3.84±6.75 days). (P=0.0001). LOS was significantly longer in respiratory diseases (18.7±17.96 days) followed by CNS diseases (12.0±15.24 days), cardiac diseases (10.77±12.72 days), and least in sepsis and septic shock (8.3±9.6 days) (P=0.0001).

Mode of ventilation and duration of ventilation
There was a significant association between mode of mechanical ventilation used and duration of ventilation, with the shortest duration in patients put on NICPAP mode (3.3±5.9 days) and the longest in PCV mode (10.2±14.7 days) (P=0.0001) (Fig. 9).

Invasive versus noninvasive ventilation regarding LOS and duration of ventilation
There was an increase in duration of ventilation in patients ventilated with invasive mode, with duration of 7.7±11.5 days, compared with 4.6±7.9 days for noninvasive mode (P=0.001).

Ventilator settings with length of stay and duration of ventilation
There was a positive correlation between PEEP and length of stay and also positive correlation between PEEP and duration of ventilation (P=0.0001).

There was a negative correlation between pressure support (PS) and duration of ventilation (P=0.05). There was no significant correlation between PS and length of stay.

RR had a positive correlation with duration of ventilation (P=0.03). RR had no significant correlation with length of stay.

FiO₂ had a positive correlation with duration of ventilation (P=0.001).

FiO₂ had a nonsignificant correlation with length of ICU stay (P=0.711).

Vt did not have any significant correlation with the duration of ventilation or length of stay (P=NS).

Discussion
Our retrospective single-center study involved 1081 mechanically ventilated patients who were admitted to the critical care department of Kasr El-Aini Hospital, Cairo University, in the period between January 2010 and December 2014.

The objective of the study was to document our daily interactions with patients subjected to MV in the Critical Care Department focusing on epidemiological characteristics, initial settings, modes of mechanical ventilation applied, and final clinical outcomes.

Several studies on mechanically ventilated patients were done to study the epidemiological characteristics of the MV patients, ventilator settings used, and/or outcome of mechanical ventilation: De Queiroz Guimarães and Rocco [3] performed a prospective cohort study involving 755 patients over an 18-month period. Esteban et al. [4] performed a multicenter prospective study involving 4968 patients over a 1-month period. Metnitz et al. [5] substudied the multicenter study (SAPS 3) involving 13,322 patients admitted to 299 ICUs from 35 countries; Goligher et al. [6] also published a review in 2009. Lonel and Walsh [7] performed a retrospective cohort study on 5552 patients admitted to three ICUs in UK from 2002 to 2006. Esteban et al. [8] conducted
another prospective cohort study involving 18,302 patients. Kim et al. [9] performed a study for an 18-month period and identified 555 patients admitted to the neuro-ICU. Our study, to the best of our knowledge, is the first to document such parameters in our region.

Demographics and comorbidities
In our study, the median age was 55 (IQR: 36–74) years and sex distribution was 53% female and 47% male patients. Metnitz et al. (5) in his study on 13,322 patients reported that the median age was 63 (48–74) years, with 60.2% male patients. Moreover, Esteban et al. [4] found that mean age was 59±17 years and 40% were females. Kim et al. [9] showed a mean age of 59.2±7.1 years [207 (37.3%) females]. In addition, Rojek-Jarmuł et al. [10] in a retrospective cohort study on 403 patients found that there were 261 (64.8%) men in the population, and the median age was 72 (IQR: 63–77) years.

Our study showed a slightly lower mean age and a slightly higher percentage of females compared with similar epidemiological studies. This may be attributed to the lower mean age of our Egyptian population and the different sex distribution in the Middle East and Africa than other European or American countries included in the previous studies.

Reason for initiation of mechanical ventilation
In our study, causes of ventilation were cardiac diseases in 41.7% (including: pulmonary edema in 15.6%, cardiogenic shock in 15.4%, cardiac arrest in 5.3%, hypovolemic shock in 4.2%, and pulmonary embolism in 1.2%), respiratory diseases in 35.8% (chest infection in 19.6%, respiratory failure in 5.4%, aspiration pneumonia in 5.2%, acute exacerbations of chronic obstructive pulmonary disease in 4%, acute respiratory distress syndrome (ARDS) in 0.7%, flail chest in 0.1%, and hypoxic arrest in 0.9%), CNS diseases in 16.9% (coma in 9.9%, postoperative delayed recovery in 5.2%, and convulsions in 1.8%), and sepsis and septic shock in 9.4%. Esteban et al. (4) showed that the main reasons for mechanical ventilation were respiratory diseases in 34% (chronic obstructive pulmonary disease (COPD) 5%, asthma 1%, pneumonia 11%, ARDS 3%, aspiration 3%, other chronic lung disease 2%, other causes of acute respiratory failure 9%), CNS in 20% (coma 19% and neuromuscular disease 1%), postoperative complications in 21%, sepsis in 9%, cardiac diseases in 11% (congestive heart failure 6% and cardiac arrest 5%), and trauma in 6%. Moreover, Rojek-Jarmuł et al. [10] reported that causes of respiratory failure were postoperative 56.3%, exacerbation of chronic obstructive pulmonary disease in 14.4%, cerebral stroke/bleeding to the CNS in 4.7%, pneumonia in 7.6%, postresuscitation disease in 4.2%, multiple organ trauma in 3%, neuromuscular disease in 2.9%, exacerbation of chronic circulatory failure in 2.7%, neoplastic disease after palliative surgery in 1.7%, encephalopathy in 1.5%, and pulmonary embolism in 0.7%.

The cause of MV may vary according to the type of the intensive care itself whether general, medical or surgical, specialized in cardiac or respiratory or neurological or hepatic, or other categories of illness. Our ICU is a general medical ICU with a relatively larger population of patients with cardiac diseases.

Modes of mechanical ventilation
The most common initial mode of MV in our study was VCV (61.8%) followed by noninvasive CPAP (15.4%), PCV (14.7%), PS–CPAP (8%), and bilevel positive airway pressure (0.1%). Similarly, Esteban et al. [8] found that VCV mode was the most common mode used and employed in ~60% of modes used Metnitz et al. [5] found that Assist/Controlled Mechanical Ventilation (AC/CMV) was the main mode of invasive ventilation (46.4%), followed by PCV (19.7%) and synchronized intermittent mandatory ventilation (SIMV)+PSV in 16.3%. PSV was used in 6.4%, SIMV in 6.3%, and CPAP in 1.6%.

Ventilator settings
In our study, Vt (mean±SD) was 440.2±76.9 ml (7.33±1.27 ml/kg IBW), PS was 16.3±1.46, PEEP was 4.46±1.52 cmH2O, RR was 15.5±1.53 breath/min, and FiO2 was 53.38±10.58. Esteban et al. [8] in his prospective cohort study found that ventilator settings were as follows: Vt=7.6±2.1 ml/kg predicted body weight, PEEP 4.2±3.8 cmH2O, and total RR 18±6 breaths/min. Trevisan and Vieira [11] in a randomized clinical trial on 65 mechanically ventilated patients reported that the mean±SD of RR was 21.2±4.9 rpm, Vt 629±0.27 ml, and PS 18.6±2.9 cmH2O.

In our study, the highest initially set PEEP was in patients with ARDS (8.22±4.19). Moreover, PEEP (mean±SD) was higher in patients ventilated for respiratory problems (mean 5.15±1.82 cmH2O), followed by CNS diseases (4.46±1.09 cmH2O), cardiac diseases (4.14±1.24 cmH2O), and lowest in patients with sepsis and septic shock (3.53±1.24 cmH2O) (P=0.0001). Vt was highest in patients ventilated for cardiac diseases (447.2±72.9 ml) followed by sepsis and septic shock (447±66.4 ml), respiratory causes (438±77.9 ml), and CNS causes (416.9±88.4 ml) (P=0.003).
Noninvasive ventilation

NIV was the initial mode of ventilation in 20% of our patients; 62% of those patients had cardiac diseases, 36% had respiratory diseases (42% of them were COPD patients), 1.2% had neurological diseases, and 0.6% had sepsis and septic shock. Metnitz et al. [5] found that NIV was used in 4.2% of all patients and was associated with an improved risk-adjusted outcome (OR: 0.79; 95% CI: 0.69–0.90). Esteban et al. [8] has reported an increased use of noninvasive positive-pressure ventilation (5% in 1998 to 14% in 2010). Demoule et al. [12] noted increased utilization of NIV (from 16 to 23% of all new initiations of MV) in French ICUs between 1997 and 2002, particularly for patients with acute on top of chronic respiratory failure and de-novo respiratory failure.

The duration of ventilation

In our study, there was a significant (P=0.001) increase in duration of ventilation in patients ventilated with invasive modes (7.7±11.5 days) compared with those on noninvasive mode (4.6±7.9 days). Trevisan and Vieira [11] reported that patients of the NPPV group had a shorter stay in the ICU and in the hospital. Duration of MV was 10.02 days for the invasive modes (7.7±11.5 days) compared with those in duration of ventilation in patients ventilated with noninvasive mode (4.6±7.9 days). Trevisan and Vieira [11] reported that patients of the NPPV group had a shorter stay in the ICU and in the hospital. Duration of MV was 10.02 days for the invasive MV group and 7.5 days for the NPPV. Ferrer et al. [13] found that the NPPV group had shorter lengths of stay in the ICU and in the hospital, without any reductions in mortality.

In our cohort study, 89.2% of patients ventilated with NICPAP mode stayed on the ventilator for less than a week. There was a significantly lower percentage of mortality in NIV (28.9%) compared with 72.2% mortality in patients with invasive modes (P=0.0001). Keenan et al. [14] in a review of several randomized controlled trials reported that NIV use decreases the occurrence of VAP, length of ICU and hospital stay, and total duration of mechanical ventilation, besides reducing patient mortality. Siirala et al. [15] in a retrospective cohort study involving 86 patients found that NIV nonusers showed a four-fold increased risk of mortality compared with NIV users. Burns et al. [16] in a meta-analysis performed in 2009 found that NIV was associated with lower mortality (risk ratio: 0.41), less VAP (risk ratio: 0.28), and shorter mechanical ventilation (7.3 days), ICU stay (6.9 days), and hospital stay (7.3 days); NIV had no effect on the probability of weaning success. Ferrer et al. [13] found a significantly higher survival rate in the NIV group. The favorable effects may be originally related to the severity of the underlying disease and not to the noninvasive mode itself, as the less severe cases are generally the ones given the chance of NIV in contrast to the more severe cases, which are immediately intubated and have invasive ventilation initiated.

Weaning

In our study, weaning trials were done in 401/1081 (37.1%) patients, of which 276 (68.8%) were successfully weaned, in comparison with 78.4% by Rojek-Jarmula et al. [10], 56.7% by Verceles et al. [17], 57.6% by Giménez. et al. [18], and 31% in the early studies by Ely-Wesley et al. [19].

The most common weaning mode used in our study was PS-CPAP (70.5%) followed by unplanned extubation (22.9%), NICPAP (2.7%), T-piece (2.7%), and SIMV (0.4%). Epstein [20] reported unplanned extubation range from 0.3 to 16%. In most cases (83%), the unplanned extubation is initiated by the patient, whereas 17% are accidental. Unplanned extubation occurred in a relatively higher incidence in our study probably owing to our policies of very minimal sedation and no patient restraint policies.

Esteban et al. [21] found that the various techniques used for weaning were T-piece trail in 24%, SIMV in 18%, PSV in 15%, SIMV+PSV in 9%, and combination of two or more methods in 33%. Esteban et al. [22] showed that the most common weaning method was PS in 36%, SIMV in 5%, SIMV and PS in 28%, intermittent CPAP in 17%, and daily SBTs in 4%. Esteban et al. [23] reported that weaning was performed with once-daily SBTs in 89%, PS reduction in 21%, SIMV in 8.5%, SIMV with PS in 22%, T-tube in 52% of attempts, CPAP in 19%, and PS in 28%.

There was no significant association between age of the patient and weaning off mechanical ventilation (P=0.094). Moreover, Giménez et al. [18] did not find any statistical association between age and type of weaning or between the type of weaning and mortality variables at the ICU.

Duration of ventilation and ICU length of stay

The duration of MV and patient outcome are determined by a complex interplay of acute and chronic diseases, MV-related complications, and local processes of care (e.g. weaning protocols) that strongly predict morbidity and mortality [24].

Duration of mechanical ventilation in our study was 6.70±10.98 days, with a median of 3 days, and ICU length of stay of the mechanically ventilated patient was 13.28±15.25 days, with median 8 days, in

A 5-year registry of mechanical ventilation Nassar et al. 259
comparison with Esteban et al. [8] who reported that duration of ventilatory support was a median of 6 days (IQR: 3–11) and length of stay in the ICU was a median of 7 days (IQR: 4–14). Nevins and Epstein [25] reported that the mean duration of MV was 8.9 days (median: 4.1 days), and the mean duration of hospital stay was 22.0 days (median: 14.0 days). Rojek-

In our patients, those with respiratory diseases as a cause of ventilation had significant longer duration of ventilation (11.3±15.7 days) followed by CNS diseases (5.95±7.38), sepsis and septic shock (5.14±6.03), and cardiac diseases (3.84±6.75). LOS was significantly longer in respiratory diseases (18.7±17.96 days) followed by CNS diseases (12.06±15.24), cardiac diseases (10.77±12.72), and least in sepsis and septic shock (8.3±9.6 days) (P=0.0001). Vallverdu et al. [26] in a prospective cohort study on 217 patients receiving mechanical ventilation reported that prolonged ventilation occurred in as many as 61% of patients with COPD, in 41% of patients with neurological disorders, and in 38% of patients with hypoxemia. However, Prakash et al. [27] in a prospective cohort study of 100 patients reported that the mean duration of ventilation was shortest in acute exacerbation of bronchial asthma (2.33 days) and longest in cases of Guillain-Barré syndrome (12.42 days).

In our study, we found that the longest ICU stay was in patients on PCV mode (17±17.9 days) and the shortest stay in patients on NICPAP (13±11.8) (P=0.003), whereas the shortest duration of ventilation was in patients put on NICPAP mode (3±5.9 days) and the longest in patients put on PCV mode (10.2±14.7 days) (P=0.0001). Trevisan and Vieira has found that length of stay in ICU was shorter in NICPAP mode at 18.9±11.3 days than invasive pressure controlled ventilation at 20.8±10.9 days. Moreover, the total MV time in NICPAP mode was 14.9±9.9 days and in PCV mode was 17.3±10.5 [11].

In our study, there was a significant (P=0.001) increase in duration of ventilation in patients ventilated with invasive mode, with a duration of 7.7±11.5 days, compared with 4.6±7.9 days for noninvasive mode. Epstein and Durbin [28] reported that the NIV patients had better outcomes, including shorter mechanical ventilation (10 vs. 17 days) and ICU stay (15 vs. 24 days).

We also found longer ICU stay in patients who were weaned off MV (20.9±19.7 days) compared with nonweaned patients (8.7±9.2) (P=0.0001). Moreover, the duration of ventilation was much longer in patients who were weaned off ventilation (11.2±15.6 days) than nonweaned patients (4.03±5.3 days) (P=0.0001). In addition, there was higher length of stay in patients who failed weaning than successfully weaned patients (32.1±22.96 vs. 10.8±11.91). Mahmood et al. [29] reported that the mean ICU LOS was significantly higher in patients with failed weaning compared with successfully weaned patients (26±12 vs. 7±3; P<0.001). Combes et al. [30] reported that prolonged ventilation was associated with an increase in mortality, morbidity, and ICU length of stay.

The duration of ventilation in our study was significantly higher in patients with failed weaning than successfully weaned patients (21.48±18.51 vs. 4.77±7.71) (P=0.0001). Prakash et al. [27] reported that 75.31% of patients were weaned off within a week and 6.79% required a weaning time of more than 2 weeks. In addition, Epstein et al. [31] reported that extubation failure was associated with higher mortality and prolonged duration of MV and hospital length of stay.

In our study, 76.6% of patients were put on mechanical ventilation for less than 1 week, 11.6% ventilated for 2 weeks, 5.1% put on mechanical ventilation for 3 weeks, and 6.8% for more than 3 weeks. Esteban et al. [23] reported that in patients intubated with acute respiratory failure, ~25% required 7 days of mechanical ventilation, and 10% remained intubated for more than 21 days. However, Estenssoro et al. [32] reported that 14.3% required ventilation for more than 21 days. Cox et al. [33] found that 14.0% of patients required MV for more than 21 days.

Complications

Complications from mechanical ventilation in our cohort of patients were ventilator-associated pneumonia in 160 (14.8%) patients; barotrauma in 66 (6.1%) patients, of which 11 cases developed tension pneumothorax; cardiopulmonary arrest in 30 (2.8%) cases; and tracheo-esophageal fistula in one (0.1%) case. Prolonged MV was seen in 6.8%, where patients stayed on MV for more than 21 days, and tracheotomy was done in 76 (7%) patients. Esteban et al. (8) reported that the incidence of VAP was 4%, barotrauma 2%, and cardiopulmonary arrest 39%.

In our study group, 160 (14.8%) patients developed VAP. Nevins and Epstein (25) found that VAP was 20.8%. De Queiroz Guimarães and Rocco (3) reported that VAP developed in 38.1% of the
patients; 45.3% were caused by gram-negative agents (*Pseudomonas aeruginosa* accounting for 22%), and multidrug-resistant organisms were identified in 43.4%.

The most common isolated organisms in our cohort were *Acinetobacter baumanii* (29.8%) followed by *Klebsiella pneumoniae* (19.2%), and *Proteus* spp. (15.2%). Sofianou *et al.* [34] found that the pathogens isolated were predominantly gram-negative bacteria (83.2%), with a high proportion of *Acinetobacter* spp. (35%). On the contrary, De Queiroz Guimarães and Rocco [3] reported that the bacteria most often isolated were *Pseudomonas aeruginosa* (22%), *Acinetobacter* spp. (14%), and methicillin-resistant *Staphylococcus aureus* (11%).

In our cohort, VAP was more common in patients with failed weaning than successfully weaned patients (18 vs. 12.5%) (*P*=0.0001). Celis *et al.* [35] also reported a higher incidence of VAP with MV for more than 3 days, higher levels of PEEP, failed weaning, and repeated intubation. However, Sofianou *et al.* [34] found that risk factors associated with VAP were MV more than 10 days (OR: 44.4, 95% CI: 2.16–26.7, *P*=0.0001), ICU length of stay of more than 10 days (OR: 9.4, 95% CI: 3.55–25.65, *P*=0.0001), and admission PaO$_2$/FiO$_2$ ratio $\sim$200 mmHg (OR: 3.4, 95% CI: 1.00–11.41, *P*=0.05). Moreover, De Queiroz Guimarães and Rocco [3] reported that the patients who developed VAP, time on MV had a median of 13 days.

**Mortality**

In our study, mortality among MV patients was 696 patients (64.4%). Mortality was significantly higher in patients ventilated because of cardiac diseases (41.8%) followed by respiratory disease (31.8%) and CNS diseases (13.8%), and lowest in patients with sepsis and septic shock (12.6%) (*P*=0.0001). A Korean study performed by Koo and Kim [36] reported that the mortality of ICU patients was 31.0%. Gillet *et al.* [37] has found that the overall mortality was 45% of all mechanically ventilated patients, and mortality was 56% among patients with severe community-acquired pneumonia. Hu *et al.* [38] studied patients with CAP on MV and showed 55.9% mortality. On the contrary, Simpson [39] found that 33% of patients with CAP died in the first 24 h of presenting to the hospital. Kim *et al.* [9] reported that mortality in patients ventilated for neurological problems was 83 (15.0%) patients during neuro-ICU stay.

We found that highest mortality was among patients who were put on mode VCV (77.5%) and lowest in NICPAP mode (28.1%). (*P*=0.0001). Nonsurvivors had significantly higher Vt than survivors (444.32±73.81 vs. 426.33±84.32 ml) (*P*=0.019) as reported by Nevins and Epstein [25], where patients with extubation failure had lower Vts (339±123 vs. 458±161 ml).

We also found that the cutoff value for tidal volume in total number of patients was 475 (7.9 ml/kg) (mean IBW: $\pm$60 kg) with specificity 78% and sensitivity 60%, and higher tidal volume values are associated with mortality and complications (*P*=0.0001). Esteban *et al.* [8] found that the cutoff value for tidal volume was 6.9±1.9 ml/kg actual body weight and also reported that the decline in Vt from 8.8±2.1 ml/kg in 1998 to 6.9±1.9 ml/kg in 2010 was associated with decreased mortality in MV patients. Moreover, Determann *et al.* [40] in a randomized controlled trial on 150 patients found that the average Vts were 6–8 ml/kg predicted body weight.

We also found that the cutoff value for PEEP was 9 with specificity 99% and sensitivity 98% and higher PEEP levels were associated with mortality and complications (*P*=0.0001). Esteban *et al.* [8] found that the cutoff value for PEEP was 7±3 cmH$_2$O and the increase in applied PEEP from 4.2±3.8 cmH$_2$O in 1998 to 7±3 cmH$_2$O in 2010 was associated with decreased mortality and complications. Hemmes *et al.* [41] in a meta-analysis of eight articles on 1669 patients reported that a Vt of 6–8 ml/kg and also a PEEP of 6–8 cmH$_2$O, decrease pulmonary complications, readmissions, ICU LOS, and even mortality, compared with ventilation with a VT of 10 ml/kg and a PEEP of 3 cmH$_2$O.

We have demonstrated the magnitude of MV use in our ICU, the epidemiology and the initial ventilation modes and parameters most commonly used, and their association with in-hospital mortality and complications. Future studies may help to study MV in each group of patients with a specific disease, define what criteria used to define ready-to-wean patients, and also whether newer modes of ventilation are beneficial to patients or not.

**Limitations**

The retrospective nature of the study with no direct intervention or direct observation of patients is a limitation. We could only register the initial first day settings and the starting weaning mode, but we could not retrieve the progressive daily changes in the settings and patient responses during the whole period of ventilation, as this was not available on the current electronic health record database.
Conclusions

(1) The duration of ventilation was 6±10 days, with a median of 3 days; length of ICU stay was 13±15 days, with a median of 8 days. The predominant indications of ventilation were cardiac diseases followed by respiratory, neurological, and sepsis and septic shock.

(2) VCV was the most common initial mode of ventilation followed by Non Invasive Continuous Positive Airway Pressure – Pressure Support (NICPAP-PS) and PCV. NIV is associated with shorter duration on mechanical ventilation and ICU stay. PS-CPAP mode was the most common weaning mode used followed by unplanned extubation, NICPAP, T-piece, and SIMV.

(3) Highest rate of successful weaning was in patients with CNS diseases followed by respiratory diseases, cardiac diseases, and least in patients with sepsis and septic shock.

(4) The duration of ventilation was longest in respiratory diseases and shortest is cardiac diseases. Complications such as cardiopulmonary arrest, pneumothorax, and VAP were more common in patients with respiratory diseases.

(5) Mortality rate in MV patients was 64%. Mortality rate was higher in patients with cardiac diseases followed by respiratory diseases, CNS diseases, and patients with septic shock. Mortality was higher with higher levels of tidal volumes, higher FiO2 levels, and lower PEEP levels. Mortality was higher in invasive ventilation than NIV. Patients with failed weaning had higher mortality.

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Conflicts of interest

There are no conflicts of interest.

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