Predicting Delayed Ventilator Weaning after Lung Transplantation: The Role of Body Mass Index

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**Background:** Weaning from mechanical ventilation is difficult in the intensive care unit (ICU). Many controversial questions remain unanswered concerning the predictors of weaning failure. This study investigates patient characteristics and delayed weaning after lung transplantation.

**Methods:** This study retrospectively reviewed the medical records of 17 lung transplantation patients from October 2012 to December 2013. Patients able to be weaned from mechanical ventilation within 8 days after surgery were assigned to an early group (n = 9), and the rest of the patients were assigned to the delayed group (n=8). Patients’ intraoperative and postoperative characteristics were collected and analyzed, and conventional weaning predictors, including rapid shallow breathing index (RSBI), were also assessed.

**Results:** The results of the early group showed a significantly shorter ICU stay in addition to a shorter hospitalization overall. Notably, the early group had a higher body mass index (BMI) than the delayed group (20.7 vs. 16.9, p = 0.004). In addition, reopening occurred more frequently in the delayed group (1/9 vs. 5/8, p = 0.05). During spontaneous breathing trials, tidal volume (TV) and arterial oxygen tension were significantly higher in the early group compared to the delayed weaning group, but differences in RSBI and respiratory rate (RR) between groups were not statistically significant.

**Conclusions:** Low BMI might be associated with delayed ventilator weaning in lung transplantation patients. In addition, instead of the traditional weaning predictors of RSBI and RR, TV might be a better predictor for ventilator weaning after lung transplantation.

**Key Words:** body mass index; lung transplantation; mechanical ventilation; weaning.

Introduction

Lung transplantation is one of the few feasible treatment options for end-stage lung disease. The first lung transplantation was described in 1963,[1] and it provided decades of survival after decades.[2] Since the first successful case, the number of transplants has continued to increase and the clinical outcomes of lung transplantation continue to improve, as the International Society of Heart and Lung Transplantation reported over 43,000 transplants worldwide, and the associated 5-year survival rate reached 53%.[3] Specifically, in Korea, the first lung transplantation was reported in 1996, and a case series of 13 patients was published in 2006.[4]

Following transplantation, the day of extubation is one of the most critical moments in the intensive care unit (ICU) stay. Early extubation after lung transplantation (within 12 hours) has been frequently reported,[5,6] but this maneuver should be performed very cautiously in select patients to avoid the serious complications associated with reintubation. The median time to extubation in lung transplantation patients was reported to be approximately 3 days, and the range was between one and 312
hours.[7,8] According to these reports, most lung transplantation patients undergo mechanical ventilator weaning and extubation while still in the ICU.

When deciding to wean patients from mechanical ventilation (MV), many parameters are considered, including demographic data, perioperative variables and laboratory data such as acceptable gas exchange. MV itself is a major determinant of ICU length of stay (LOS). One prospective study specific to lung surgery reported that preoperative body mass index (BMI) prior to lung volume reduction surgery is a sensitive measure of the patient’s nutritional state, and a low BMI correlates to prolonged postoperative MV.[9] In addition to BMI, Lee et al.[10] also published that the median ICU LOS following a single lung transplantation was 5 days, and that pulmonary hypertension and poor immediate postoperative oxygenation (ratio of the partial pressure of arterial oxygen to the fraction of inspired oxygen [PaO2/FiO2] of less than 200 mmHg) were good predictors of a prolonged ICU stay.[10]

Extubation and weaning from MV performed in a timely manner are critical to ICU management to reduce ICU LOS. To identify risk factors for prolonged MV after unilateral or bilateral lung transplantation, we retrospectively reviewed the medical records of lung transplantation patients who were weaned from MV. We classified and analyzed clinical data that may impact the ability to wean a patient from MV, and organized this data by the preoperative, intraoperative and postoperative periods. Lung mechanics and arterial blood gas analysis (ABGA) during spontaneous breathing trials (SBTs) were investigated, in addition to the well-known weaning predictors of tidal volume (TV), respiratory rate (RR), and rapid shallow breathing index (RSBI).[11-13]

Materials and Methods

This retrospective study was approved by the Institutional Review Board (IRB) of Severance Hospital (Ref: 4-2013-0927), and the need for informed consent was waived by the IRB. Seventeen patients aged 18 years or older who were admitted to the ICU from October 2012 after unilateral or bilateral lung transplantation were enrolled. Exclusion criteria included early death within the immediate postoperative ICU stay and prolonged MV (> 3 months). Data were collected retrospectively by reviewing electronic medical records, and the same surgeon performed all surgeries.

Demographic data and intraoperative and postoperative variables that may impact the ability to wean a patient from MV were investigated. Demographic data included age, gender, height, weight, BMI, and comorbid illness. Preoperative pulmonary function testing, echocardiography and 6-minute walking distance were also collected. Intraoperative variables included operation time, fluid intake, urine output, blood transfusion history, estimated blood loss, and salvaged blood from the Cell Saver (Cell Saver 5 System, Haemonetics, Braintree, MA, USA). ABGA, TV, and RR throughout the SBTs were recorded. RSBI was calculated from TV and RR.

Unless a contraindication to the SBT was present, such as acute rejection or severe bleeding, a spontaneous awakening trial (SAT) and SBT were initiated and evaluated by the multidisciplinary team, which included the surgeon, pulmonologists, anesthesiologists, pharmacists, and nurses. According to some studies, no difference in the percentage of patients passing the SBT or the percentage of patients successfully extubated between T-tube trial and low levels of pressure support (PS),[14,15] low levels of PS less than 10 cmH2O and T-tube trial were used as SBT in this study. In addition, ABGA was performed 60 minutes after the SBT. If the respiratory pattern, gas exchange, hemodynamic stability and subject comfort were sufficient to pass the SBT, extubation for endotracheally intubated patients or weaning from MV for patients with tracheostomies were done. If there was any controversy about the SBT results, the SBT was extended to 120 minutes. After a maximum duration of 120 minutes, the multidisciplinary critical care team decided whether to extubate or wean. When patients failed an initial SBT, the team reviewed possible reversible etiologies for failure, such as respiratory load (increased work of breathing, reduced compliance due to pneumonia or edema, airway difficulty), cardiac dysfunction, neuromuscular dysfunction, neuropsychological complications, metabolic disturbance, inappropriate nutrition and anemia. After correcting these etiologies, SBTs were repeated daily in order to successfully extubate the patient at the earliest possible time.

Notably, SBTs were immediately aborted in the following situations: 1. Clinical assessment and subjective indices suggesting agitation, anxiety, depressed mental status, perspiration, cyanosis, increased accessory muscle activity and dyspnea, 2. Objective measurements showing a PaO2 < 60 mmHg on FiO2 ≥ 0.5 or a percutaneous oxygen saturation (SpO2) ≤ 88%, arterial carbon dioxide partial pressures (PaCO2) > 65 mmHg, RR > 45 breaths/min, RSBI > 105 breaths/min/L, heart rate (HR) over 140 beats/min or sustained increase or decrease of > 20%, systolic blood pressure (SBP) > 180 mmHg or SBP < 90 mmHg, and 3. Measurements showing newly developed or aggravated
cardiac arrhythmia.

Once the median duration of MV was identified, the patients were divided into two groups, either the early or delayed group, based on median duration of MV.

**Statistical analysis**

Data were presented as the median (interquartile range) or the number (percentage) of patients. Data analysis was performed using the Statistical Package for the Social Sciences (SPSS, Version 18; SPSS Inc., Chicago, IL, USA). Comparisons between the two groups were analyzed using the Mann-Whitney test for continuous data and using the $\chi^2$ test or Fisher’s exact test for categorical data. A p-value less than 0.05 was considered statistically significant.

**Results**

A total of 17 patients were enrolled in this study (Table 1). The median patient age was 52 years. Hospital death occurred in three patients. Etiologies of end-stage lung disease included idiopathic pulmonary fibrosis (9 patients), complications from bone marrow transplantation (3 patients), bronchiectasis (1 patient), usual interstitial pneumonia (1 patient), lymphangioleiomyomatosis (1 patient), dermatomyositis (1 patient) and chronic obstructive pulmonary disease (COPD) (1 patient).

In this study, the median duration of MV was 8.0 days. Brochard [16] proposed that patients who are difficult to wean often require up to three SBTs or may take as long as 7 days from the first SBT to achieve successful weaning. In our study, unless there was a contraindication to the SBT, such as acute rejection or severe bleeding, the first SBT was usually initiated the day after surgery. Therefore, patients requiring up to 7 days from the first failed SBT (post-op day 8) to achieve successful weaning were assigned to the delayed group. Thus, the early and delayed groups were defined by a MV duration of 8 days. Nine patients were classified into the early group and eight patients were classified into the delayed group. The first SBT failure rate was similar between the two groups (2/9 vs. 3/8, $p = 0.62$).

In the early group, patients were older (55 vs. 48 years, $p = 0.04$) and had less frequent reoperation rates (1/9 vs. 5/8, $p = 0.05$) and had less frequent reoperation rates (1/9 vs. 5/8, $p = 0.05$).

| Table 1. Characteristics of patients with early and delayed weaning after lung transplantation |

<table>
<thead>
<tr>
<th>Overall</th>
<th>Early group (n = 9)</th>
<th>Delayed group (n = 8)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, yr</td>
<td>52 (42-58)</td>
<td>55 (50-65)</td>
<td>48 (35-53)</td>
</tr>
<tr>
<td>Sex, M</td>
<td>12 (70.6)</td>
<td>7 (77.8)</td>
<td>5 (62.5)</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>19.38 (16.92-20.81)</td>
<td>20.72 (19.13-21.94)</td>
<td>16.92 (13.50-19.25)</td>
</tr>
<tr>
<td>BSA, m²</td>
<td>1.55 (1.44-1.70)</td>
<td>1.69 (1.55-1.73)</td>
<td>1.49 (1.36-1.55)</td>
</tr>
<tr>
<td>KONOS registration to op., d</td>
<td>75 (8-256)</td>
<td>75 (13-295)</td>
<td>102 (6-211)</td>
</tr>
<tr>
<td>MV duration, d</td>
<td>8.0 (3.2-21.7)</td>
<td>3.7 (2.4-5.9)</td>
<td>21.7 (13.1-40.4)</td>
</tr>
<tr>
<td>Hospital stay, d</td>
<td>42.0 (27.8-71.8)</td>
<td>28.5 (22.5-46.3)</td>
<td>75.0 (43.5-122.8)</td>
</tr>
<tr>
<td>ICU stay, d</td>
<td>13.0 (5.5-28.5)</td>
<td>6.0 (5.0-8.0)</td>
<td>24.5 (16.0-41.8)</td>
</tr>
<tr>
<td>Re-open</td>
<td>6 (35.3)</td>
<td>1 (11.1)</td>
<td>5 (62.5)</td>
</tr>
<tr>
<td>Mortality</td>
<td>3 (17.6)</td>
<td>3 (33.3)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Comorbid illness</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRF</td>
<td>1 (5.9)</td>
<td>0 (0)</td>
<td>1 (12.5)</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>5 (29.4)</td>
<td>3 (33.3)</td>
<td>2 (25.0)</td>
</tr>
<tr>
<td>Long-term steroid use</td>
<td>11 (64.7)</td>
<td>6 (66.7)</td>
<td>5 (62.5)</td>
</tr>
<tr>
<td>Smoking</td>
<td>20.0 (0-30.0)</td>
<td>25.0 (0-32.0)</td>
<td>7.5 (0-28.8)</td>
</tr>
<tr>
<td>Ventilator use</td>
<td>6 (35.3)</td>
<td>3 (33.3)</td>
<td>3 (37.5)</td>
</tr>
<tr>
<td>ECMO use</td>
<td>1 (5.9)</td>
<td>1 (11.1)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Preoperative evaluation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Six-minute walk test</td>
<td>195 (105-313)</td>
<td>280 (75-320)</td>
<td>140 (122-270)</td>
</tr>
<tr>
<td>FEV1 (%)</td>
<td>31 (21-47)</td>
<td>31 (23-44)</td>
<td>35 (18.6-41)</td>
</tr>
<tr>
<td>FVC (%)</td>
<td>40 (26-55)</td>
<td>37 (28-63)</td>
<td>42 (53-19)</td>
</tr>
<tr>
<td>EF (%)</td>
<td>65 (58-69)</td>
<td>65 (53-70)</td>
<td>63 (60-67)</td>
</tr>
<tr>
<td>RVSP*, mmHg</td>
<td>45 (38-60)</td>
<td>50 (43-71)</td>
<td>42 (32-55)</td>
</tr>
<tr>
<td>Donor information</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Donor age, yr</td>
<td>40 (26-44)</td>
<td>40 (28-44)</td>
<td>40 (22-49)</td>
</tr>
<tr>
<td>Ischemic time, min</td>
<td>247 (176-341)</td>
<td>247 (229-327)</td>
<td>247 (147-382)</td>
</tr>
</tbody>
</table>

* RVSP was measured by echocardiography or right-sided catheterization. BMI: Body Mass Index (kg/m²); BSA: Body Surface Area (m²); KONOS: Korean Network for Organ Sharing; MV: mechanical ventilation; ICU: intensive care unit; CRF: Chronic renal failure; ECMO: extracorporeal membrane oxygenation; FEV1: forced expiratory volume in 1 second; FVC: forced vital capacity; EF: ejection fraction (%); RVSP: right ventricular systolic pressure.
Table 2. Intraoperative variables of patients with early and delayed weaning after lung transplantation

<table>
<thead>
<tr>
<th></th>
<th>Overall</th>
<th>Early group (n = 9)</th>
<th>Delayed group (n = 8)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation time, h</td>
<td>6.85 (6.05-8.15)</td>
<td>6.85 (5.43-7.40)</td>
<td>7.60 (6.52-9.58)</td>
<td>0.18</td>
</tr>
<tr>
<td>Unilateral/Bilateral</td>
<td>3/14</td>
<td>2/7</td>
<td>1/7</td>
<td>0.55</td>
</tr>
<tr>
<td>Total fluid intake, ml</td>
<td>8420 (5950-10400)</td>
<td>7820 (5250-9225)</td>
<td>9275 (6838-15850)</td>
<td>0.29</td>
</tr>
<tr>
<td>Colloid, ml</td>
<td>1000 (500-1500)</td>
<td>1000 (500-1250)</td>
<td>1250 (1000-1500)</td>
<td>0.19</td>
</tr>
<tr>
<td>pRBC, units</td>
<td>7 (3-13)</td>
<td>6 (3-9)</td>
<td>4 (3-16)</td>
<td>0.36</td>
</tr>
<tr>
<td>FFP, units</td>
<td>3 (1-5)</td>
<td>3 (2-5)</td>
<td>4 (1-9)</td>
<td>0.66</td>
</tr>
<tr>
<td>Plt conc, units</td>
<td>11 (6-12)</td>
<td>6 (3-12)</td>
<td>12 (6-12)</td>
<td>0.27</td>
</tr>
<tr>
<td>Cell saver, ml</td>
<td>865 (488-2583)</td>
<td>700 (450-1210)</td>
<td>2530 (500-4140)</td>
<td>0.14</td>
</tr>
<tr>
<td>Urine output, ml</td>
<td>2270 (1295-3708)</td>
<td>2050 (1360-3708)</td>
<td>2385 (1218-5145)</td>
<td>1.00</td>
</tr>
<tr>
<td>Blood loss, ml</td>
<td>2500 (2050-4500)</td>
<td>2500 (1925-4035)</td>
<td>5075 (2000-9500)</td>
<td>0.30</td>
</tr>
<tr>
<td>ECMO time, min</td>
<td>309 (256-388)</td>
<td>278 (231-333)</td>
<td>337 (282-460)</td>
<td>0.12</td>
</tr>
</tbody>
</table>

pRBC: packed red blood cells; FFP: fresh frozen plasma; Plt conc: platelet concentrate; ECMO: extracorporeal membrane oxygenation.

Table 3. Postoperative variables of patients with early and delayed weaning after lung transplantation

<table>
<thead>
<tr>
<th></th>
<th>Overall</th>
<th>Early group (n = 9)</th>
<th>Delayed group (n = 8)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECMO use (%)</td>
<td>8 (47.1)</td>
<td>1 (11.1)</td>
<td>7 (87.5)</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>ECMO duration, d</td>
<td>3 (1-9)</td>
<td>1</td>
<td>3 (1-11)</td>
<td>0.26</td>
</tr>
<tr>
<td>VAP (%)</td>
<td>7 (41.2)</td>
<td>1 (11.1)</td>
<td>6 (75.0)</td>
<td>0.02</td>
</tr>
<tr>
<td>Bleeding &gt; 1000 ml/d</td>
<td>5 (29.4)</td>
<td>1 (11.1)</td>
<td>4 (50.0)</td>
<td>0.13</td>
</tr>
<tr>
<td>Arrhythmia (%)</td>
<td>3 (17.6)</td>
<td>1 (11.1)</td>
<td>2 (25.0)</td>
<td>0.58</td>
</tr>
<tr>
<td>AKI (%)</td>
<td>2 (11.8)</td>
<td>0 (0)</td>
<td>2 (25.0)</td>
<td>0.21</td>
</tr>
<tr>
<td>CRRT (%)</td>
<td>1 (5.9)</td>
<td>0 (0)</td>
<td>1 (12.5)</td>
<td>0.47</td>
</tr>
<tr>
<td>Sepsis (%)</td>
<td>2 (11.8)</td>
<td>0 (0)</td>
<td>2 (25.0)</td>
<td>0.21</td>
</tr>
<tr>
<td>Re-intubation (%)</td>
<td>2 (11.8)</td>
<td>0 (0)</td>
<td>2 (25.0)</td>
<td>0.21</td>
</tr>
</tbody>
</table>

ECMO: extracorporeal membrane oxygenation; VAP: ventilator associated pneumonia; AKI: acute kidney injury; CRRT: continuous renal replacement therapy.

Table 4. Parameters associated with the success of the first spontaneous breathing trial

<table>
<thead>
<tr>
<th></th>
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<th>Early group (n = 9)</th>
<th>Delayed group (n = 8)</th>
<th>p value</th>
</tr>
</thead>
</table>
| Respiratory parameters before SBT
  TV, mL                   | 406 (357-434)    | 418 (386-467)       | 361 (345-408)         | 0.043   |
  RR (breaths/min)         | 16 (14-23)       | 16 (14-19)          | 23 (15-24)            | 0.097   |
  RSBI (breaths/min/L)     | 41.7 (34.7-63.0)| 36.6 (31.4-44.1)    | 59.5 (40.7-66.0)      | 0.083   |
  Ineffective cough        | 12 (70.6)        | 6 (66.7)            | 6 (75.0)              | 1.0     |
  Sputum > moderate        | 14 (82.4)        | 6 (66.7)            | 8 (100)               | 0.21    |
| ABG before SBT
  pH                       | 7.46 (7.43-7.48)| 7.46 (7.44-7.47)    | 7.45 (7.40-7.50)      | 0.81    |
  PaO2                     | 134.6 (115.0-151.7)| 145.4 (131.4-162.5)| 122.8 (93.7-134.6)    | 0.016   |
  PaCO2                    | 38.3 (31.6-42.6) | 41.0 (30.8-45.0)    | 36.8 (31.6-41.3)      | 0.56    |
  PaO2/FiO2                | 337 (291-434)    | 415 (306-449)       | 327 (251-363)         | 0.10    |
| ABG one hour after SBT
  PaO2                     | 118.6 (98.7-147.3)| 134.4 (111.0-155.1)| 93.6 (80.4-129.3)     | 0.045   |
  PaCO2                    | 36.9 (31.3-47.1) | 36.9 (29.1-48.4)    | 37.2 (34.2-46.4)      | 0.72    |
  PaO2 decrease (%)        | 13.2 (3.5-17.5)  | 13.2 (3.1-15.7)     | 13.5 (-3.4-19.8)      | 0.64    |
  PaCO2 decrease (%)       | 6.9 (-15.3-9.5)  | 9.0 (-14.0-15.0)    | -0.1 (-28.0-10.1)     | 0.29    |
| Weaning results
  First SBT-successful extubation, h | 10.2 (1.9-61.1) | 3.6 (1.9-21.8)      | 47.9 (3.9-171.9)      | 0.18    |
  First SBT failure (%)    | 5 (29.4)         | 2 (22.2)            | 3 (37.5)              | 0.62    |
  MV duration, d           | 8.0 (3.3-21.7)   | 3.7 (2.4-5.9)       | 21.7 (13.1-40.4)      | 0.001   |

SBT: spontaneous breathing trial; TV: tidal volume; RR: respiratory frequency; RSBI: rapid shallow breathing index (respiratory frequency to tidal volume ratio); ABG: arterial blood gas; PaO2: arterial oxygen tension; PaCO2: arterial carbon dioxide tension; MV: mechanical ventilation.
0.05) than the delayed group (Table 1). Predictably, the ICU and
hospital LOS were longer in the delayed group. Also, BMI (20.7
vs. 16.9 kg/m², p < 0.01) and BSA (1.7 vs. 1.4 m², p = 0.02) were
significantly higher in the early group.

Analysis of intraoperative and postoperative variables
showed no significant differences between the groups, except
for more frequent extracorporeal membrane oxygenation
(ECMO) use and ventilator-associated pneumonia (VAP) in the
delayed group (Table 2 and 3). ECMO was used when the im-
mediate postoperative lung function was insufficient to ad-
equately oxygenate the entire body. VAP, acute rejection and the
general preoperative condition of the patient could affect post-
operative lung function.

In the early group, the TV just before the SBT was sig-
ificantly greater (418 vs. 361 ml, p = 0.04) compared to the de-
layed group, while respiratory rate and RSBI were not sig-
nificantly different between groups (Table 4). PaO₂ measure-
ments prior to SBT and 1 hour after SBT were significantly
higher in the early group than the delayed group, but PaO₂/FiO₂
before SBT was not significantly different. However, patients
were given different proportions of oxygen and were given oxy-
gen via different methods after SBT. Therefore, a higher PaO₂
before SBT and 1 hour after SBT in the early group does not al-
low for conclusions to be drawn.

Discussion

The results of the present study show that a low BMI is asso-
ciated with prolonged MV after lung transplantation. In addi-
tion, larger tidal volumes before the SBT are associated with a
shorter MV duration in this patient population, while the con-
tventional weaning indicator, RSBI, did not predict early wean-
ing from MV.

BMI and skeletal muscle mass have been reported to be good
indicators of clinical outcomes in critically ill patients. In crit-
cially ill patients, the obesity-mortality paradox is a well-known
phenomenon among the intensivists. In an observational study
of approximately 154,000 ICU patients, BMIs less than 18.5 kg/m²
demonstrated the highest mortality risk, while obese patients
with BMIs ranging between 30 and 39.9 kg/m² showed the low-
est risk of death (odds ratio of 0.86, 95% confidence interval
0.83-0.90).[17] In addition, Gupta et al.[18] showed that low
BMIs less than 18.5 kg/m² were associated with increased mort-
tality in 793 surgical ICU patients. Similarly, sarcopenia, based
on muscle cross-sectional area at the third lumbar vertebra, was
associated with fewer ventilator-free and ICU-free days in eld-
ery patients.[19] An additional retrospective investigation re-
vealed that low BMI was associated with a higher risk of death
in acute lung injury patients on MV[20], and a similar associa-
tion between low BMI less than 21 and delayed weaning from MV in
chronic obstructive lung disease patients has been demonstrated.[21]
De la Torre et al.[22] reported that there was no correlation be-
tween low BMI and delayed weaning in patients after lung
transplantation. However, their study defined low BMI to be
less than 20 kg/m², not 18.5 kg/m², which may have blunted
their effects. Because in the other study, the Toronto Lung
Transplant Group revealed that lower BMI less than 17 was as-
associated with higher risk of 90-day mortality in the patient un-
dergoing lung transplantation.[23]

Initially, BMI measurements were introduced to be a marker
of the overall nutrition status of the human body. Because ade-
quate nutrition support can improve respiratory muscle con-
tractility and the subsequent ability to expectorate sputum, the
duration of MV in critically ill patients could be prolonged in
malnourished patients. Therefore, BMI is an important refer-
ence index that can be used to estimate MV duration and predict
weaning from MV for post-transplantation patients, as the re-
results of this study have indicated.

MV weaning covers the entire process of liberating the pa-
tients from mechanical support and from the endotracheal tube.
Weaning from MV starts with a clinical picture suggesting that
the patient could tolerate spontaneous breathing. Then, an as-
essment of readiness to wean, a SBT, and extubation are carried
out.[24] Previous studies have reported that the weaning failure
rate after a single SBT is between 26 and 42%.[25,26]

If weaning is delayed, patients are exposed to unnecessary
discomfort and the risk of complications, including stress ulcer,
deep vein thrombosis or pulmonary embolism, and VAP, are
increased. For these patients, the increased cost of care due to
prolonged hospital and ICU stays can be devastating. The in-
cidence of unplanned extubation ranges from 0.3 to 16%,[27] and
almost half of patients who underwent unplanned extubation
during the weaning period did not require reintubation.[28]
These findings suggest that a significant number of critically ill
patients are enduring unnecessary lengths of MV and intubation.
Esteban et al.[29] demonstrated that mortality increases with in-
creasing duration of MV, in part because of the complications of
prolonged MV like VAP and airway trauma.[30] Coplin et
al.[31] reported that mortality of brain-injured patients was 12%
if there was no delay in extubation, but mortality was increased
to 27% in cases of delayed extubation. Moreover, MV has been
consistently associated with an increased cost of care of up to
Although a relatively small percentage (6%) of ventilated patients experience prolonged MV, these patients consume 37% of ICU resources.[33] Additionally, failure to extubate is associated with high mortality and morbidity by inducing deleterious effects such as aspiration, atelectasis, and pneumonia.[34]

Patients undergoing lung transplantation should be cautiously weaned from MV in a timely manner. Most lung transplantation patients are physically debilitated because transplantation tends to be the last treatment option in end-stage lung disease. They usually suffer from long-term malnutrition and sarcopenia, lack of physical activity due to oxygenation failure, and cardiac comorbidities such as right heart failure.

In the literature, a limited number of predictors for ventilator weaning or extubation failure have been suggested.[11-13] One study reported that the immediate postoperative PaO2 to FiO2 ratio, a history of preexisting pulmonary hypertension, and the pulmonary blood flow distribution were good predictors of the ICU length of stay following single lung transplantation.[10] In addition to these predictors, our study suggests that preoperative BMI and larger TVs before the SBT may be reasonable predictors of weaning in lung transplantation patients. In previous literature, TV was not commonly highlighted as a predictor of delayed weaning or weaning failure. However, RSBI, which was noticed because of its high predictive value,[12] showed some trends, but the small study population may explain why RSBI failed to be a significant predictor of weaning success. Because the RR was similar between the two groups during the SBTs, RSBI was not statistically significant. The patients with end-stage lung disease had long-term exposure to hypoxia and hypercapnia, so their respiratory drive was decreased. Also, their postoperative pain was controlled with high-dose opioids, specifically remifentanil via intravenous infusion, which may contribute to the patients breathing more deeply and slowly after lung transplantation.

In this study, older age was associated with early weaning. When we compared the younger age group (< 53 years) to the older group, the younger group also had a lower BMI. One thought is that end-stage lung disease rapidly wastes the metabolic reserve in younger patients. Total energy expenditure, which includes resting energy expenditure, is known to decrease with the aging process.[35] Therefore, it is possible that elderly patients are more resistant to malnutrition because weight-adjusted energy expenditure is lower in the elderly.[36]

Prolonged MV is associated with VAP. As demonstrated in COPD patients, higher BMIs could be associated with early weaning from MV,[21] possibly due to improved immunity. Therefore, the relationship between BMI and VAP warrants further investigation.

Compared to other studies, the duration of MV in this study was longer, while weaning failure after the first successful SBT occurred in only two patients. These results suggest that there is room for a faster weaning process in our practice. In addition, the limited number of cases in this study requires further analysis of the variables we chose to study. The small number of the patients in this study (n = 17) is one reason why the predictive power was not analyzed by a receiver operating characteristic curve.

In the present study, we demonstrated MV more than 8 days after unilateral or bilateral lung transplantation to be associated with lower BMI and smaller tidal volume before SBT. Notably, postoperative comorbidities associated with prolonged MV were found to be ECMO use and VAP.

References

