Establishing failure predictors for the planned extubation of overweight and obese patients

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Abstract

We investigated failure predictors for the planned extubation of overweight (body mass index [BMI] = 25.0–29.9) and obese (BMI ≥ 30) patients. All patients admitted to the adult intensive care unit (ICU) of a tertiary hospital in Taiwan were identified. They had all undergone endotracheal intubation for >48 h and were candidates for extubation. During the study, 595 patients (overweight = 458 [77%]; obese = 137 [23%]) with planned extubation after weaning were included in the analysis; extubation failed in 34 patients (5.7%). Their mean BMI was 28.5 ± 3.8. Only BMI and age were significantly different between overweight and obese patients. The mortality rate for ICU patients was 0.8%, and 2.9% for inpatients during days 1–28; the overall in-hospital mortality rate was 8.4%. Failed Extubation group patients were significantly older, had more end-stage renal disease (ESRD), more cardiovascular system-related respiratory failure, higher maximal inspiratory pressure (MIP), lower maximal expiratory pressure (MEP), higher blood urea nitrogen, and higher ICU- and 28-day mortality rates than did the Successful Extubation group. Multivariate logistic regression showed that cardiovascular-related respiratory failure (odds ratio [OR]: 2.60; 95% [confidence interval] CI: 1.16–5.80), ESRD (OR: 14.00; 95% CI: 6.25–31.35), and MIP levels (OR: 0.94; 95% CI: 0.90–0.97) were associated with extubation failure. We conclude that the extubation failure risk in overweight and obese patients was associated with cardiovascular system-related respiratory failure, ESRD, and low MIP levels.

Introduction

The prevalence of obesity is increasing worldwide and it has become a global public health threat. Obesity increases the risks of diabetes mellitus (DM), coronary artery disease (CAD), stroke, renal function impairment, respiratory dysfunction, and malignancy [1–4]. Because obesity has so many pathophysiologic effects upon all major organ systems and increases the prevalence of comorbidities, it is also significantly associated with higher risks of morbidity and mortality [5–7]. Therefore, an increasing number of obese patients need to be admitted to...
the intensive care unit (ICU) for critical care, and ICUs will inevitably have to treat a greater number of critically ill obese patients [8, 9].

Acute respiratory failure is one of the most frequent reasons that patients are transferred to the ICU. This condition is usually treated using endotracheal intubation with invasive mechanical ventilation, regardless of whether the patient is obese or normal weight [10–12]. A patient who has survived an acute condition that requires intubation must first be weaned from invasive ventilation. The critical care physician must then do a weaning test and decide the appropriate timing for extubation. However, even after a comprehensive evaluation, extubation fails for a significant percentage of patients, who then require reintubation. Several studies [13–17] have identified useful factors to accurately predict successful extubation. Several physiological parameters of pulmonary mechanisms [13,16,17], such as respiratory frequency-to-tidal volume (the rapid shallow breathing index [RSBI]), thoracic compliance, oxygenation, maximum occlusion pressure, and dynamic changes through the course of a spontaneous breathing trial (SBT), and airway protection capabilities, including mental status, cough strength, and secretion loads have been identified as possible predictors of successful extubation. However, the lung function of overweight patients is different from that of normal weight and underweight patients [18–21]. Thus, we aimed to determine what would predict the successful extubation of overweight and obese patients.

Methods

Patients and hospital setting

This study was done at the Chi Mei Medical Center, a 1288-bed tertiary medical center with 96 ICU beds for adults. The ICU is staffed by critical care attending physicians, senior residents, nurses, respiratory therapists, dietitians, physical therapists, and clinical pharmacists. Each team makes rounds at least once daily, and respiratory therapists manage all mechanical ventilation (MV) patients, including SBTs: T-piece or pressure support ventilation (PSV) for 30–120 minutes and weaning them from MV processes. All patients who required an invasive MV using an endotracheal tube for 48 hours and who were prepared for a scheduled extubation according to a weaning protocol and physicians’ judgment between January 2010 and December 2011 were eligible for inclusion. Each patient’s ICU admission weight and height were used to calculate their body mass index (BMI = weight in kg/height in m^2). We measured weight in ICU patients with electronic weighing beds (Chang Gung Medical Technology Co., Ltd). Only adult (> 18 years old) patients with a BMI ≥ 25 kg/m^2 were included in this study. For patients who required repeated intubation, only the first episode was included in the analysis.

Variables measured

The medical records of all included patients were retrospectively reviewed and information was collected about age, gender, type of ICU, level of consciousness, intubation pathway (nose or mouth), why intubation was required, underlying diseases, and comorbidities, laboratory examination results, organ failure, intubation details, disease severity, length of ICU and hospital stays, reintubation rate, and mortality rate. After a patient had completed a successful SBT, the weaning parameters—respiratory rate, tidal volume, minute ventilation, RSBI, maximal inspiratory pressure (MIP), maximal expiratory pressure (MEP), and cuff leak test (CLT) —were measured when the patients were presumed ready for extubation. To accurately measure MIP, we measured 3 times with an interval of 5–6 seconds (2–3 breaths), and the value was recorded as the maximal data within these 3 checks. Additionally, we held the breath of unconscious and of uncooperative patients for 20 seconds from the end of inspiration to
obtain the level of MIP. Thus, we improved the accuracy of MIP measurements. All data were routinely retrospectively collected and then analyzed. The Chi Mei Medical Center Institutional Review Board approved the study and specifically waived informed consent (IRB NO: 10206–005).

Definitions

CLT scores were 2+ (audible flow without a stethoscope), 1+ (audible flow with a stethoscope), and N (negative; no audible flow with a stethoscope). Extubation failure was defined as reintubation within 48 hours of extubation. Overweight was defined as a BMI of 25.0–29.9 kg/m² and obesity as a BMI of ≥ 30 kg/m². Causes of respiratory failure were classified as the pulmonary system (upper airway obstruction, acute respiratory distress syndrome, chronic obstructive pulmonary diseases, pneumonia, malignant effusion, lobar collapse, asthma attack), cardiovascular system (congestive heart failure, pericarditis, cardiomyopathy, acute myocardial infarction, endocarditis), neurological system (status epilepticus, stroke), renal system (acute renal failure), gastrointestinal system, and others, as previously described [22,23].

Statistical analysis

Continuous variables are reported as mean ± standard deviation (SD). Categorical variables are presented as n (%). In addition, the differences in baseline characteristics and clinical variables between the Successful and Failed Extubation groups were evaluated using a Student’s t test for continuous variables and a Pearson χ² test for categorical variables. Those significantly associated with failed extubation in a univariate analysis (P < 0.05) were tested for interaction using a multivariate logistic regression analysis. Univariate and multivariate logistic regression analyses were used to calculate the odds ratios (ORs) and 95% confidence intervals (CIs) of significant variables to determine the association between predictive variables and successful extubation. SAS 9.4 for Windows (SAS Institute, Cary, NC, USA) was used for all analyses. Significance was set at P < 0.05 (two-tailed).

Results

Demographic characteristics

We enrolled 1934 patients who had been scheduled for a first-time extubation after more than 48 h of invasive MV (an endotracheal tube) after we had excluded eight patients without available BMI data (S1 File). More than half (55.9%; n = 1082) of the patients had a normal body weight (BMI = 18.5 to < 25), 257 (13.3%) were underweight (BMI < 18.5), and 595 (30.8%) were overweight or obese (BMI = ≥ 25). All patients were followed up until the primary outcome: in-hospital death or survival to discharge.

We analyzed 595 patients (mean age: 63.6 ± 15.8 years; range: 20–97 years; ≥ 65 years old: n = 283 [47.4%]; men: n = 403 [67.7%]; mean BMI: 28.5 ± 3.8) (Table 1) treated with > 48 h of MV and who underwent a planned extubation after weaning; the extubation of 34 patients (5.7%) failed. The most frequent causes of extubation failure were hemodynamic instability (n = 10), excess secretion (n = 8), upper airway obstruction (n = 8), oxygen failure (n = 6), and encephalopathy (n = 2). There were 458 (77%) overweight and 137 (23%) obese patients, 27 of whom had a BMI > 35. Pulmonary, cardiovascular, and neurological failures were the three most common etiologies of respiratory failure. The Acute Physiology and Chronic Health Evaluation (APACHE) II, Therapeutic Intervention Scoring System (TISS), and Glasgow coma scale scores upon ICU admission were 18.1 ± 6.8, 29.0 ± 7.9, and 11.2 ± 3.6, respectively. Endotracheal intubation via the oral route was done in > 95% of the patients. The most common
underlying comorbidities were diabetes mellitus (DM) \( (n = 227 \text{ [38.2%]} \) and stroke \( (n = 174 \text{ [29.2%]} \). ICU stays were \( 10.4 \pm 6.9 \) days long and hospital stays were \( 27.7 \pm 22.4 \) days long. The overall in-hospital mortality rate was 8.4% \( (n = 50) \), the overall ICU rate was 0.8%, and the 28-day rate was 2.9%. BMI was significantly \( (P < 0.001) \) different between the overweight and obese patients, and obese patients were significantly younger than were overweight patients \( (60.5 \pm 16.3 \text{ vs. } 64.6 \pm 15.6 \text{ years, } P = 0.008) \) (Table 1).

### Table 1. Characteristics of overweight (BMI: 25–29.9) and obese (BMI \( \geq 30 \)) patients treated with mechanical ventilation (MV) for > 48 h and undergoing planned extubation \( (n = 595) \).

| Characteristics                           | Variable   | Overweight (BMI: 25–29.9) | Obese (BMI \( \geq 30 \)) | P*  |
|-------------------------------------------|------------|----------------------------|----------------------------|-----|
| Male                                      | 403 (67.7) | 315 (68.8)                 | 88 (64.2)                  | 0.319 |
| Age (years)                               | 63.6 ± 15.8| 64.6 ± 15.6                | 60.5 ± 16.3                | 0.008 |
| Elderly (\( \geq 65 \text{ years old} \)) | 283 (47.4) | 220 (48.0)                 | 62 (45.3)                  | 0.568 |
| Body mass index (BMI)                     | 28.5 ± 3.8 | 27.0 ± 1.4                 | 33.4 ± 5.0                 | < 0.001 |
| Overweight (BMI: 25–29.9) \( [n \text{%}] \) | 458 (77)   |                            |                            |     |
| Obese (BMI \( \geq 30 \)) \( [n \text{%}] \) | 137 (23)   |                            |                            |     |
| Cause of respiratory failure              |            |                            |                            |     |
| Pulmonary system                          | 144 (24.2) | 105 (22.9)                 | 39 (28.5)                  | 0.184 |
| Neurological system                       | 141 (23.7) | 105 (22.9)                 | 36 (26.3)                  | 0.418 |
| Cardiovascular system                     | 133 (22.4) | 108 (23.6)                 | 25 (18.2)                  | 0.189 |
| Gastrointestinal system                   | 89 (15.0)  | 74 (16.2)                  | 15 (10.9)                  | 0.134 |
| Renal system                              | 39 (6.6)   | 26 (5.7)                   | 13 (9.5)                   | 0.114 |
| Others                                    | 48 (8.1)   | 39 (8.5)                   | 8 (6.6)                    | 0.463 |
| APACHE II                                 | 18.1 ± 6.8 | 18.2 ± 6.8                 | 18.1 ± 6.9                 | 0.869 |
| Therapeutic Intervention Scoring System (TISS) Scale | 29.0 ± 7.9 | 29.1 ± 8.0               | 28.8 ± 7.6                 | 0.695 |
| Glasgow coma scale                        | 11.2 ± 3.6 | 11.3 ± 3.7                 | 11.1 ± 3.5                 | 0.703 |
| Number of comorbidities                   | 1.2 ± 0.9  | 1.6 ± 1.8                  | 2.0 ± 2.9                  | 0.994 |
| Comorbidity                               |            |                            |                            |     |
| Diabetes mellitus (DM)                    | 227 (38.2) | 166 (36.2)                 | 61 (44.5)                  | 0.080 |
| Stroke                                    | 174 (29.2) | 135 (29.5)                 | 39 (28.5)                  | 0.820 |
| Coronary artery disease (CAD)             | 152 (25.5) | 124 (27.1)                 | 28 (20.4)                  | 0.118 |
| Cancer                                    | 82 (13.8)  | 63 (13.8)                  | 19 (13.9)                  | 0.973 |
| Chronic obstructive pulmonary disease (COPD) | 60 (10.1) | 47 (10.3)                   | 13 (9.5)                   | 0.792 |
| End-stage renal disease                   | 51 (8.6)   | 37 (8.1)                   | 14 (10.2)                  | 0.432 |
| Liver cirrhosis                           | 18 (3.0)   | 14 (3.1)                   | 4 (2.9)                    | 0.935 |
| Nasal endotracheal tube                   | 26 (4.4)   | 21 (4.6)                   | 5 (3.6)                    | 0.638 |
| Endotracheal tube size [median inner diameter: cm (IQR)] | 7.5 (7.0–7.5) | 7.5 (7.0–7.5) | 7.5 (7.5–7.5) |     |
| Intubation depth (cm)                     | 22.6 ± 1.8 | 22.6 ± 1.9                 | 22.6 ± 1.7                 | 0.946 |
| Intubation period before extubation (h)   | 180.9 ± 133.7 | 176.3 ± 133.9 | 196.4 ± 132.4 | 0.123 |
| Length of intensive care unit (ICU) stay (days) | 10.4 ± 6.9 | 10.3 ± 6.8 | 10.8 ± 7.1 | 0.414 |
| Length of hospital stay (days)            | 27.7 ± 22.4 | 27.9 ± 235 | 27.1 ± 18.1 | 0.706 |
| Reintubation within 48 h                  | 34 (5.7)   | 28 (6.1)                   | 6 (4.4)                    | 0.443 |
| In-hospital mortality rate                | 50 (8.4)   | 38 (8.3)                   | 12 (8.8)                   | 0.864 |

*Comparison between Overweight and Obese groups
Categorical variables are expressed as number \( n \text{%} \) and continuous variables as means ± standard deviation (SD) or median (interquartile range [IQR]).

APACHE: Acute Physiology and Chronic Health Evaluation.

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Comparison of patients in the Failed and Successful Extubation groups

There were many significant differences between the Failed and the Successful Extubation group patients. Those in the Failed Extubation group were older, had more end-stage renal disease (ESRD), and had a higher blood urea nitrogen (BUN) level (Table 2). They also had more respiratory failure because of cardiovascular system failure, had a less-negative MIP, and a less-positive MEP (Table 2).

Failed Extubation group patients had higher mortality rates than did Successful Extubation group patients (Table 3). They were also transferred to the Respiratory Care Center and Respiratory Care ward because it was difficult to wean them from MV Consequently, they had longer ICU and hospital stays, and higher hospital costs than did patients in the Successful Extubation group (Table 3).

Multivariate analysis

Multivariate logistic regression showed that cardiovascular system failure-induced respiratory failure (OR: 2.60; 95% CI: 1.16–5.80), ESRD (OR: 14.00; 95% CI: 6.25–31.35), and lower MIP levels (OR: 0.94; 95% CI: 0.90–0.97) were associated with failed extubation (Table 4).

Discussion

Our most important finding was that the MIP level was significantly associated with the outcome of extubation. Although impaired respiratory muscle loading might be induced by dysfunctional respiratory system mechanics and high ventilation demands, our finding indicated that extubation failure might be closely related to the power of respiratory muscle to overcome the burden of a large body size. In contrast, the RSBI, which is most commonly used to evaluate the ability of patients to breathe spontaneously and to be successfully weaned from MV, was not significantly different between the Failed and Successful Extubation groups. Studies [24, 25] on neurology patients report that the RSBI does not predict extubation failure. Although others [26–28] have identified many variables, e.g., age, mental status, oxygenation impairment, and the severity of acute illnesses, as risk factors for extubation failure and reintubation, we did not find that these variables were independent predictors of reintubation. This might be partly because of our unique study population: overweight and obese patients. It indicates that more studies are needed to investigate and establish prediction models of failed and successful extubation in specific populations.

We also found that ESRD was independently associated with extubation failure. A recent study [29] on surgical ICUs reported that an elevated BUN level (> 8.2 mmol/L) was an independent risk factor for reintubation (OR: 3.66; 95% CI: 1.97–6.80) in patients with a median BMI of 26.9 (no reintubation group; n = 699) and with a median BMI of 26.2 (reintubation group; n = 65). Another study [30] reported that acute kidney injury (OR: 2.98; 95% CI: 2.13–4.02) was associated with reintubation after coronary artery bypass grafting surgery. Overall, renal failure can be a risk factor of extubation failure in overweight patients and other populations.

A third important finding is that the risk of extubation failure was higher when the cause of respiratory failure was a cardiovascular system failure. In the present study, more than 40% of our patients with extubation failure had cardiovascular system failure that had required the patients to be intubated. Obesity itself is an important risk factor for the development of cardiovascular diseases [31]; therefore, physicians should more carefully assess the timing of extubation, especially for obese patients with cardiac failure. However, additional studies are required to confirm this finding.
### Table 2. Comparison of Failed and Successful Extubation groups.

|                                     | Failed Extubation | Successful Extubation | P     |
|-------------------------------------|-------------------|-----------------------|-------|
| **Age (years)**                     | 69.5 ± 11.4       | 63.2 ± 16.0           | 0.004 |
| **Male [%]**                        | 20 (58.8)         | 383 (68.3%)           | 0.253 |
| **Body mass index (BMI) (kg/m^2)** | 28.0 ± 2.3        | 28.5 ± 3.9            | 0.422 |
| **Overweight (BMI: 25–29.9) [%]**  | 28 (82.4)         | 430 (76.6)            | 0.443 |
| **Obese (BMI > 30) [%]**           | 6 (17.6)          | 131 (23.4)            | 0.443 |
| **Medical department [%]**         | 14 (41.2)         | 255 (45.5)            | 0.626 |
| **Severity**                        |                   |                       |       |
| APACHE II                          | 18.2 ± 7.3        | 18.1 ± 6.8            | 0.935 |
| TISS Scale                         | 30.7 ± 9.0        | 28.9 ± 7.8            | 0.191 |
| Glasgow coma scale                 | 11.7 ± 4.0        | 11.2 ± 3.6            | 0.409 |
| **Number of comorbidities**        | 1.4 ± 1.0         | 1.2 ± 0.9             | 0.343 |
| **Comorbidity [%]**                |                   |                       |       |
| End-stage renal disease            | 17 (50.0)         | 34 (6.1)              | < 0.001 |
| Diabetes mellitus (DM)             | 15 (44.1)         | 212 (37.8)            | 0.461 |
| Stroke                             | 12 (35.3)         | 140 (25.0)            | 0.180 |
| Coronary artery disease (CAD)      | 9 (26.5)          | 165 (29.4)            | 0.714 |
| Cancer                             | 5 (14.7)          | 77 (13.7)             | 0.872 |
| COPD                               | 3 (8.8)           | 57 (10.2)             | 0.802 |
| Liver cirrhosis                    | 0 (0)             | 18 (3.2)              | 0.289 |
| **Cause of respiratory failure [%]**|                   |                       |       |
| Pulmonary system                   | 6 (17.6)          | 138 (24.6)            | 0.358 |
| Cardiovascular system              | 15 (44.1)         | 118 (21.0)            | 0.002 |
| Neurological system                | 8 (23.5)          | 133 (23.7)            | 0.981 |
| Renal system                       | 3 (8.8)           | 36 (6.4)              | 0.582 |
| Gastrointestinal system            | 2 (5.9)           | 87 (15.5)             | 0.126 |
| Others                             | 0 (0)             | 48 (8.6)              | 0.075 |
| **Intubation period before extubation (h)** | 188.6 ± 112.6 | 180.4 ± 134.9 | 0.729 |
| **Parameter before extubation**    |                   |                       |       |
| Respiratory rate (breaths/min)     | 18.7 ± 5.4        | 17.9 ± 5.1            | 0.401 |
| Tidal volume (mL)                  | 429.9 ± 162.3     | 459.2 ± 161.7         | 0.312 |
| Minute ventilation (L/min)         | 9.30 ± 4.08       | 9.38 ± 3.11           | 0.889 |
| RSBI (breaths/min/L)               | 57.6 ± 27.0       | 53.6 ± 26.4           | 0.402 |
| MIP (cm H$_2$O)                    | -30.7 ± 12.0      | -41.7 ± 15.0          | 0.011 |
| MEP (cm H$_2$O)                    | 32.8 ± 9.1        | 65.8 ± 30.4           | 0.001 |
| **Cuff leak test**                 |                   |                       |       |
| N                                  | 2 (5.9)           | 18 (3.2)              | 0.401 |
| +                                  | 6 (17.6)          | 81 (14.4)             | 0.607 |
| ++                                 | 26 (76.5)         | 432 (77.0)            | 0.943 |
| **Laboratory examinations**        |                   |                       |       |
| pH                                 | 7.44 ± 0.048      | 7.446 ± 0.046         | 0.534 |
| PaCO$_2$ (mmHg)                    | 37.1 ± 5.2        | 39.0 ± 6.2            | 0.082 |
| PaO$_2$ (mmHg)                     | 89.3 ± 27.6       | 91.7 ± 23.6           | 0.577 |
| PaO$_2$/FiO$_2$ (mmHg)             | 296.3 ± 112.2     | 326.7 ± 90.9          | 0.070 |
| Hemoglobin (Hb) (g/dl)             | 11.1 ± 2.0        | 11.1 ± 2.0            | 0.960 |
| Blood urea nitrogen (BUN) (mg/dl)  | 43.5 ± 39.3       | 28.5 ± 23.9           | 0.040 |
| Creatinine (mg/dl)                 | 2.40 ± 2.17       | 1.62 ± 2.10           | 0.058 |
Finally, our patients with a failed extubation, like those in other studies [22,26,32], had worse outcomes, including higher mortality and longer hospital stays. However, the extubation failure rate in the present study was only 5.7%, significantly lower than those in two of those studies [26,32]. The difference might be attributable to different study designs and weaning protocols. Our finding suggests, however, that it is possible to select patients who can be successfully extubated after a comprehensive assessment, including a conventional weaning profile, underlying disease, and the cause of acute respiratory failure. It is also possible that the low failure rate in our study was caused by delayed extubation (the average duration of MV was 7–8 days in the present study). However, delayed extubation is also reported to be associated with worse outcomes, such as pneumonia, length of stay in the ICU and in the hospital, and mortality [33]. Therefore, it is important for physicians to weigh risks versus benefits between delayed and early extubation. We recommend that for overweight and obese patients, physicians should carefully evaluate MIP level, the cause of respiratory failure, and comorbid ESRD before scheduling an extubation.

This study has some limitations. It was done in a single tertiary medical center, the final decision to extubate was made by ICU physicians. Extubation can be delayed until patients show improvement in all variables. Therefore, our findings might not be generalizable to other populations. Because this is the first report that focuses on the risk factors of extubation failure in overweight and obese patients, it offers some useful insights. Although we tried to adjust for all possible confounding factors in this retrospective study, we might have missed some other cofactors, such as previously prescribed and taken sedatives. Further investigations are warranted.

### Table 2. (Continued)

|                | Failed Extubation | Successful Extubation | P  |
|----------------|-------------------|-----------------------|----|
| Albumin (mg/dl)| n = 34            | n = 561               |    |
| 2.9 ± 0.5      | 2.8 ± 0.6         | 0.264                 |    |

Categorical variables are expressed as n (%) and continuous variables as means ± standard deviation (SD).

APACHE: Acute Physiology and Chronic Health Evaluation; TISS: Therapeutic Intervention Scoring System; COPD: chronic obstructive pulmonary disease; RSBI: rapid shallow breathing index; MIP: maximum inspiratory pressure; MEP: maximum expiratory pressure; PaCO\(_2\): partial pressure of carbon dioxide in arterial blood; PaO\(_2\): partial oxygen tension in arterial blood; FiO\(_2\): fractional concentration of oxygen in inspired gas.

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### Table 3. Outcomes of Failed and Successful Extubation groups.

| Variable                          | All n = 595 | Failed Extubation n = 34 | Successful Extubation n = 561 | P   |
|-----------------------------------|-------------|--------------------------|--------------------------------|-----|
| Intensive care unit (ICU) mortality| 5 (0.8)     | 3 (8.8)                  | 2 (0.4)                         | <0.001 |
| 28-day mortality                  | 17 (2.9)    | 5 (14.7)                 | 12 (2.1)                        | <0.001 |
| Transferred to respiratory care center | 45 (7.6) | 25 (73.5)               | 20 (3.6)                        | <0.001 |
| Transferred to respiratory care ward | 4 (0.7)  | 3 (8.8)                  | 1 (0.2)                         | <0.001 |
| ICU stay (days)                   | 10.4 ± 6.9  | 14.4 ± 7.2              | 10.2 ± 6.8                      | <0.001 |
| Hospital stay (days)              | 27.7 ± 22.4 | 36.5 ± 24.1            | 27.2 ± 22.2                     | 0.018 |
| Hospital cost (NT$10,000)         | 35.7 ± 31.6 | 49.8 ± 31.5            | 34.9 ± 31.4                     | 0.007 |

Categorical variables are expressed as n (%) and continuous variables as means ± standard deviation (SD).

NT$: New Taiwan dollars (US$1 = ca. NT$32.5).

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Conclusion

The risk of extubation failure in overweight and obese patients was associated with MIP level, cardiovascular system failure-related intubation, and underlying ESRD.

Supporting information

S1 File. Dataset of study subjects.

(XLS)

Author Contributions

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References

1. Eliasson B, Liakopoulos V, Franzen S, Näslund I, Svensson AM, Ottersson J, et al. (2015) Cardiovascular disease and mortality in patients with type 2 diabetes after bariatric surgery in Sweden: a nationwide, matched, observational cohort study. Lancet Diabetes Endocrinol 3:847–854. https://doi.org/10.1016/S2213-8587(15)00334-4 PMID: 26429401

2. Lu JL, Molnar MZ, Naseer A, Mikkelsen MK, Kalantar-Za deh K, Kovesdy CP. (2015) Association of age and BMI with kidney function and mortality: a cohort study. Lancet Diabetes Endocrinol 3:704–714. https://doi.org/10.1016/S2213-8587(15)00128-X PMID: 26235959

3. Dehlendorff C, Andersen KK, Olsen TS (2014) Body mass index and death by stroke: no obesity paradox. JAMA Neurol 71:978–984. https://doi.org/10.1001/jamaneurol.2014.1017 PMID: 24886975

4. Arnold M, Pandeya N, Byrnes G, Renehan PAG, Stev ens GA, Ezzati PM, et al. (2015) Global burden of cancer attributable to high body-mass index in 2012: a population-based study. Lancet Oncol 6:36–46.

5. Vaughan RW, Conahan TJ 3rd (1980) Part I: cardiopulmonary consequences of morbid obesity. Life Sci 26:2119–2127. PMID: 6995766

6. [No authors listed] (1998) Clinical Guidelines on the Identification, Evaluation, and Treatment of Overweight and Obesity in Adults—The Evidence Report. National Institutes of Health. Obes Res 6 Suppl 2:51s–209s.

7. Alpert MA, Hashimi MW (1993) Obesity and the heart. Am J Med Sci 306:117–123. PMID: 8362892

8. Honiden S, McArdle JR (2009) Obesity in the intensive care unit. Clin Chest Med 30:581–599. https://doi.org/10.1016/j.ccm.2009.05.007 PMID: 19700054

Table 4. The predictors of failed planned-extubation within 48 h.

| Variable                        | Univariate Analysis | Multivariate Analysis |
|---------------------------------|---------------------|-----------------------|
|                                 | Odds Ratio | 95% CI | P   | Odds Ratio | 95% CI | P   |
| Age                             | 1.03       | 1.00–1.05 | 0.025 |             |         |     |
| Cardiovascular failure          | 2.96       | 1.46–6.01 | 0.003 | 2.60        | 1.16–5.80 | 0.020 |
| End-stage renal disease         | 15.50      | 7.28–33.03 | < 0.001 | 14.0        | 6.21–31.35 | < 0.001 |
| Maximal inspiratory pressure    | 0.93       | 0.90–0.97 | 0.001 | 0.94        | 0.90–0.97 | 0.001 |
| Maximal expiratory pressure     | 0.980      | 0.96–0.99 | 0.006 |             |         |     |

https://doi.org/10.1371/journal.pone.0183360.t004
9. Joffe A, Wood K (2007) Obesity in critical care. Curr Opin Anaesthesiol 20:113–118. https://doi.org/10.1097/ACO.0b013e3280803d5f PMID: 17413393

10. Krishna SG, Hinton A, Oza V, Hart PA, Swei E, El-Dika S, et al. (2015) Morbid obesity is associated with adverse clinical outcomes in acute pancreatitis: a propensity-matched study. Am J Gastroenterol 110:1608–1619. https://doi.org/10.1038/ajg.2015.343 PMID: 26482587

11. Duarte AG, Justino E, Bigler T, Grady J. (2007) Outcomes of morbidly obese patients requiring mechanical ventilation for acute respiratory failure. Crit Care Med 35:732–737. https://doi.org/10.1097/01.CCM.0000256842.39767.41 PMID: 17255878

12. Morino M, Toppino M, Forestieri P, Angriani L, Aliax ME, Scopinaro N. (2007) Mortality after bariatric surgery: analysis of 13,871 morbidly obese patients from a national registry. Ann Surg 246:1002–1009; discussion 1007–1009. https://doi.org/10.1097/SLA.0b013e31815c404e PMID: 18043102

13. Liu Y, Wei LQ, Li GQ, Lv FY, Wang H, Zhang YH, et al. (2010) A decision-tree model for predicting extubation outcome in elderly patients after a successful spontaneous breathing trial. Anesth Analg 111:1211–1218. https://doi.org/10.1213/ANE.0b013e3181f4e82e PMID: 20841406

14. Mokhlesi B, Tulaimat A, Gluckman TJ, Wang Y, Evans AT, Corbridge TC. (2007) Predicting extubation failure after successful completion of a spontaneous breathing trial. Respir Care 52:1710–1717. PMID: 18028561

15. Salam A, Tilluckdharry L, Amoateng-Adjepong Y Manthous CA. (2004) Neurologic status, cough, secretions and extubation outcomes. Intensive Care Med 30:1334–1339. https://doi.org/10.1007/s00134-004-2231-7 PMID: 14999444

16. Yang KL, Tobin MJ (1991) A prospective study of indexes predicting the outcome of trials of weaning from mechanical ventilation. N Engl J Med 324:1445–1450. https://doi.org/10.1056/NEJM199105233242101 PMID: 2023603

17. Su WL, Chen YH, Chen CW, Yang SH, Su CL, Perng WC, et al. (2010) Involuntary cough strength and extubation outcomes for patients in an ICU. Chest 137:777–782. https://doi.org/10.1378/chest.07-2808 PMID: 20097804

18. Mehta JH, Cattano D, Brayanov JB, George EE (2017) Assessment of perioperative minute ventilation in obese versus non-obese patients with a non-invasive respiratory volume monitor. BMC Anesthesiol 26:1710–1717. PMID: 22396721

19. Watson RA, Pride NB, Thomas EL, Fitzpatrick J, Durighe l G, McCarthy J, et al. (2010) Reduction of total lung capacity in obese men: comparison of total intrathoracic and gas volumes. J Appl Physiol 108:1605–1612. https://doi.org/10.1152/japplphysi.01267.2009 PMID: 20299612

20. Ko R, Ramos L, Chalela JA (2009) Conventiona l weaning parameters do not predict extubation failure in neurocritical care patients. Neurocrit Care 10:269–273. https://doi.org/10.1007/s12028-008-9181-9 PMID: 19184557

21. Namer SN, Barbas CS (2011) Predictive parameters for weaning from mechanical ventilation. J Bras Pneumol 37:669–679. PMID: 22042401

22. Thille AW, Harrois A, Schortgen F, Brun-Buisson C, Brochard L. (2011) Outcomes of extubation failure in medical intensive care unit patients. Crit Care Med 39:2612–2618. https://doi.org/10.1097/CCM.0b013e3182282a5a PMID: 21765357

23. Cheng AC, Cheng KC, Chen CM, Hsing SC, Sung MI. (2011) The outcome and predictors of failed extubation in intensive care unit patients—the elderly is an important predictor. Int J Gerontol 5:206–211.

24. Ko R, Ramos L, Chalela JA (2009) Conventional weaning parameters do not predict failure of mechanical ventilatory support in elderly critically ill patients. Neurocrit Care. 10:269–273. https://doi.org/10.1007/s12028-008-9181-9 PMID: 39184557

25. Namer SN, Barbas CS (2011) Predictive parameters for weaning from mechanical ventilation. J Bras Pneumol 37:669–679. PMID: 22042401

26. Thille AW, Harrois A, Schortgen F, Brun-Buisson C, Brochard L. (2011) Outcomes of extubation failure in medical intensive care unit patients. Crit Care Med 39:2612–2618. https://doi.org/10.1097/CCM.0b013e3182282a5a PMID: 21765357

27. Miu T, Joffe AM, Yanez ND, Khandelwal N, Dagal AH, Deem S, et al. (2014) Predictors of reintubation in critically ill patients. Respir Care 59:178–185. https://doi.org/10.4187/respcare.02527 PMID: 23882103

28. Namen AM, Ely EW, Tatter SB, Case LD, Lucia MA, Smith A, et al. (2001) Predictors of successful extubation in neurosurgical patients. Am J Respir Crit Care Med 163:658–664. https://doi.org/10.1164/ajcc.163.3.2003060 PMID: 11254520

29. Piriyapatsom A, Williams EC, Waak K, Ladha KS, Eikermann M, Schmidt UH. (2016) Prospective observational study of predictors of re-intubation following extubation in the surgical ICU. Respir Care 61:306–315. https://doi.org/10.4187/respcare.04269 PMID: 26556899
30. Jian L, Sheng S, Min Y, Zhongxiang Y. (2013) Risk factors for endotracheal re-intubation following coronary artery bypass grafting. J Cardiothorac Surg 8:208. https://doi.org/10.1186/1749-8090-8-208 PMID: 24209453

31. Mandviwalla T, Khalid U, Deswal A (2016) Obesity and cardiovascular disease: a risk factor or a risk marker? Curr Atheroscler Rep 18:21. https://doi.org/10.1007/s11883-016-0575-4 PMID: 26973130

32. Frutos-Vivar F, Esteban A, Apezteguia C, González M, Arabi Y, Restrepo MI, et al. (2011) Outcome of reintubated patients after scheduled extubation. J Crit Care 26:502–509. https://doi.org/10.1016/j.jcrc.2010.12.015 PMID: 21376523

33. Coplin WM, Pierson DJ, Cooley KD, Newell DW, Rubenfeld GD. (2000) Implications of extubation delay in brain-injured patients meeting standard weaning criteria. Am J Respir Crit Care Med 161:1530–1536. https://doi.org/10.1164/ajrccm.161.5.9905102 PMID: 10806150