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Risk factors and clinical consequences of early extubation failure in lung transplant recipients

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KEYWORDS:
lung transplantation;
extubation failure;
reintubation;
tracheostomy;
survival

BACKGROUND: Prolonged intubation following lung transplantation is thought to delay recovery, yet a paucity of data exists regarding risk factors and outcomes related to extubation failure.
METHODS: We performed a single-center, retrospective analysis of 238 lung transplant recipients between January 1, 2018, and December 31, 2022, to identify risk factors for extubation failure (intubation greater than 3 days, reintubation, and/or need for tracheostomy). We also assessed short-term outcomes relative to extubation success.
RESULTS: In this cohort, 144 patients (60%) were extubated successfully while 94 patients experienced extubation failure; 10 (11%) were intubated greater than 3 days, 9 (9%) were reintubated, 34 (36%) required tracheostomy after reintubation, and 41 (44%) underwent empiric tracheostomy. Recipient height and female sex, lung allocation score, 6-minute walk distance, donor ischemic time, ex-vivo perfusion, donor smoking history, intraoperative transfused red blood cells (packed red blood cells (PRBCs)), primary graft dysfunction at time zero, and comatose sedation state at day 2 were associated with extubation failure on univariate analysis (all $p < 0.01$), whereas comatose state [(odds ratio) OR = 84.95 (95%confidence interval (CI) 17-423), $p < 0.01$], donor smoking [OR = 5.41 (95%CI 1.73-16.92), $p < 0.01$], primary graft dysfunction at T0 [OR = 2.02 (95%CI 1.22-3.34), $p < 0.01$], and PRBCs [OR = 1.19 (95%CI 1.06-1.34, $p < 0.01$] were independently associated with extubation failure on multivariate analysis. Reintubation and empiric tracheostomy were associated with similarly prolonged intensive care unit and hospital length of stay, while tracheostomy was also associated with protracted inpatient rehabilitation, increased functional impairment, and increased 6-month mortality.
CONCLUSIONS: Specific baseline donor and recipient demographics and intraoperative variables are associated with greater risk for post-transplant extubation failure. Patients with extubation failure have worse short-term outcomes.
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Background

Postoperative management following lung transplantation requires a nuanced and proactive approach, as care during these first few days can have a lasting impact on long-term outcomes.[1] This is particularly true in the contemporary era of transplantation where demographics are increasingly skewed toward older, sicker patients with increasingly limited reserve.[2] A key aspect of promoting active patient participation in the recovery process is ventilator liberation and extubation. In fact, delayed extubation in both the lung transplant and nontransplant population is strongly associated with protracted intensive care unit (ICU) and hospital length of stay (LOS), increased risk of iatrogenesis and decreased 1-year patient survival.[3-5] Timely extubation, and resultant improvements in wakefulness, secretion clearance, and active physical rehabilitation, are vital for patient success. As such, lung allograft recipients are ideally extubated within 24 to 48 hours post-transplant.[6] In fact, some institutions aim for extubation in the operating room when feasible.[7] Unfortunately, postoperative complications, such as primary graft dysfunction (PGD), hemorrhage, pain, diaphragm weakness, frailty, and pneumonia, can interfere with timely extubation and result in prolonged endotracheal intubation, reintubation, and/or need for tracheostomy. An inability to be extubated by 72 hours post-transplant, colloquially known as "extubation failure" is common, with a reported incidence of 10% to 50%.[6] For lung transplant recipients experiencing extubation failure, early tracheostomy is often considered; however, the ideal timing for tracheostomy remains unknown; the currently accepted practice of tracheostomy within 7 to 14 days of intubation in the critical care population cannot readily be generalized to lung transplant recipients due to considerable differences in these populations.[8]

Early case series of lung transplant cohorts have identified several risk factors of extubation failure, including bilateral transplant, intraoperative cardiopulmonary bypass, pneumonia, PGD > 2 at 48 hours, and Eastern Cooperative Oncology Group performance status.[9,10] More recently, Huddleston et al demonstrated that pulmonary vascular disease, bilateral transplantation, and PGD were risk factors for a composite endpoint of death or tracheostomy within 30-days post-transplant.[11] Finally, Li et al identified preoperative extracorporeal membrane oxygenation (ECMO), advanced age, transplant type, and inability to expectorate as risk factors for extubation failure in their cohort of 107 patients.[12] While these studies are a helpful start in understanding risk factors of extubation failure in lung transplant recipients, it is difficult to interpret and apply earlier findings to contemporary practice given that patients are sicker, donor parameters more liberal, and surgical techniques and intraoperative management have evolved.[2,13]

Our primary aim was to identify early potential risk factors for extubation failure. In particular, we focused on baseline recipient demographics, donor factors, surrogates of chest wall physiology, and intraoperative traits that have not been previously assessed. These data may inform decision making on timing of tracheostomy.

Methods

We performed a single-center, retrospective observational study (Institutional Review Board #210566) of consecutive adult lung transplant recipients age greater than 18 years that were transplanted between January 1, 2018, and December 31, 2022. Patients who underwent combined organ transplantation or redo lung transplantation, who had a tracheostomy at the time of transplant, or who died within 72 hours post-transplant were excluded. Criteria for lung transplant candidates at our center were consistent with established International Society of Heart and Lung Transplant guidelines.[14] During the study period, patients with a body mass index (BMI) less than 35 kg/m^2 were eligible for consideration, and there were no limitations regarding chronologic age. Most bilateral lung transplant procedures were performed via clamshell incision and with venoarterial extracorporeal membrane oxygenation cardiopulmonary support intraoperatively. Postoperatively, patients were initially managed with goal tidal volumes of 6 to 8 cc/kg ideal body weight, keeping peak inspiratory pressures less than 30 cm H_2O. Sedation was protocolized to maximize wakefulness as assessed by Richmond Agitation Sedation Score every shift. Bronchoscopies were performed as needed based on clinical judgment, though all patients received an airway exam within the first 5 days. We aimed to maintain a central venous pressure of 10 cm H_2O with a mean systolic blood pressure of 60, using fluids, vasopressors, inotropes, or diuretics as clinically indicated. Patients requiring invasive mechanical ventilatory support with a $PaO_2/FiO_2 < 100$ and plateau pressures > 30 cm H_2O were considered for ECMO support.[15] All patients received basiliximab induction followed by tacrolimus (target trough 10-14 ng/ml), mycophenolate mofetil 1000 mg twice daily, and methylprednisolone 250 mg every 8 hours for 3 doses followed by prednisone 20 mg daily.[16] Disposition following index hospitalization was determined by a team of inpatient physical and occupational therapists. Once patients were discharged to an ambulatory setting, they were mandated to ambulatory physical therapy 3 times weekly for a minimum of 24 sessions. At the initial rehabilitation appointment, a 6-minute walk test was performed.

Extubation protocol and tracheostomy management

Patients who were hemodynamically stable, maintained sufficient oxygenation and ventilation ($SpO_2 > 93\%$, pH > 7.35 with $PaCO_2 < 50$ mm Hg) on minimal ventilator settings ($FiO_2 < 50\%$, and positive end-expiratory pressure < 5 cm H_2O), received a thoracic epidural catheter for pain control, and were minimally sedated (goal Richmond Agitation Sedation Score of 0) and eligible for daily spontaneous breathing trials. If a patient failed a spontaneous breathing trial and was unlikely to be liberated from the ventilator expeditiously (per the intensive care unit and thoracic surgery attendings), then tracheostomy was pursued. Tracheostomy tubes were maintained until patients could breathe without mechanical support for > 48 hours, expectorate secretions without need for tracheal suctioning, and swallow without risk of aspiration.

Definition of variables

Extubation failure was defined as a combined endpoint of patients in the 95th percentile for duration of the endotracheal tube post-transplantation (> 3 days), need for reintubation, and/or need for tracheostomy. Abdominal girth was measured via abdominal and pelvic CT scans that were obtained as part of the pretransplant evaluation process. Scans within 6 months of transplantation were included, or within 1-year of transplant if BMI did not change by more than 1 kg/m^2. Abdominal girth was measured on the axial cuts at the L3 spinous process level independently by 2 investigators (K.C.C. and A.J.T.) that were trained by a radiology attending; the reported value is the mean of the 2 measurements.[17]

Statistics

Continuous variables were described as median with interquartile range and categorial variables as proportions. Univariate comparisons between groups were made using the Fisher's Exact Test, Chi-square test, or Mann-Whitney U-test, as appropriate. Multivariate logistic regression analysis was performed using covariates that were demonstrated statistical significance ($p < 0.05$) in univariate analyses. Differences in outcomes between multiple subgroups were performed using Kruskal-Wallis testing, with further comparisons between subgroups performed by posthoc Dunn testing. Statistical analysis was performed using StataBEv17 (Statacorp LLC, College Station, TX).

Results

Type of extubation failure within the cohort

A total of 242 patients were transplanted between 2018 and 2022 of which 4 patients met exclusion criteria. Of the 238 patients included, 197 patients were initially extubated. The median time to extubation was 1 day (interquartile range (IQR) 1-2); 187 (95%) of patients were extubated before 3 days. Overall, 95 patients (40%) met criteria for extubation failure, defined as either intubation for > 3 days, need for reintubation, and/or need for tracheostomy (see Figure 1). Nine of the 95 patients (10%) required reintubation, but were subsequently extubated successfully, whereas 34 patients (36%) were reintubated and then underwent subsequent tracheostomy. Forty-one patients (44%) underwent tracheostomy without prior extubation ("empiric tracheostomy"). Of the 76 patients requiring tracheostomy, median time to tracheostomy was 3 days (IQR 2-4). Median duration of the tracheostomy tube was 17 days (IQR = 12-39). There was no difference in tracheostomy tube duration in patients that were reintubated prior to tracheostomy vs those that underwent empiric tracheostomy [16 days (IQR 13-28) vs 18 days (IQR 9-43), $p = 0.90$]. In this cohort, there was only one complication related to tracheostomy (major bleeding related to soft tissue injury around the stoma). The majority (46 of 53 patients) of patients requiring ECMO support post-transplant experienced extubation failure.

Recipient, donor, and intraoperative variables

Baseline pretransplant demographics and perioperative details of the cohort are described in Table 1. On univariate analysis, female sex, lung allocation score, 6-minute walk distance (6MWD), ex-vivo lung perfusion (EVLP), and donor smoking history greater than 20 pack-years were each significantly associated with extubation failure. Perioperative characteristics associated with extubation failure include donor total ischemic time, transfused blood products during the intraoperative period, PGD grade immediately postoperatively, and comatose sedation state on postoperative day 2 (Richmond Agitation and Sedation Scale= −4 or −5). On multivariate logistic regression analysis comatose sedation state on post-operative day#2, donor smoking, PGD grade immediately postoperation, and intraoperative transfusion of packed red blood cells (PRBCs) were all significantly associated with extubation failure, after controlling for recipient height and sex, EVLP, total ischemic time, lung allocation score, and 6MWD (Table 2).

Outcomes

Short-term outcomes associated with extubation failure are presented in Table 3; extubation failure was associated with increased ICU LOS [14 days (IQR 10-26) vs 4 days (IQR 4-

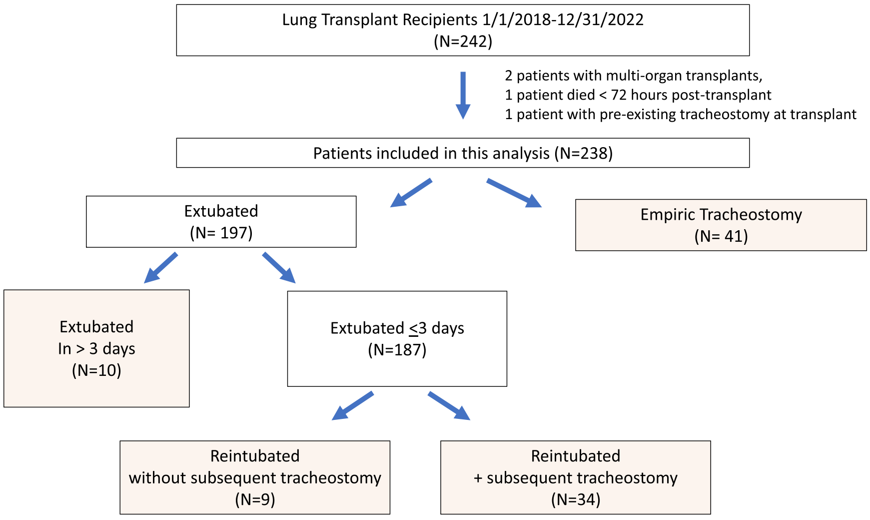

Figure 1 Incidence of extubation failure within the study population.

Table 1 Baseline Demographics Associated with Extubation Failure

Demographic	Extubation failure (N = 94)	Extubation success (N = 144)	*p*-value
Recipient factors			
Age (years)	61 (54-64)	61 (55-66)	0.54
Female sex	51 (54%)	48 (33%)	**< 0.01**
Bilateral lung transplant	75 (80%)	101 (70%)	0.13
Lung disease group			0.19
Obstructive	16 (17%)	37 (26%)	
Pulmonary vascular	4 (4%)	2 (1%)	
Suppurative	3 (3%)	8 (6%)	
Interstitial	71 (76%)	97 (67%)	
Diabetes (pretransplant)	16 (17%)	21 (15%)	0.72
Height (cm)	167.6 (160.0-175.3)	172.7 (165.1-177.8)	**< 0.01**
Body mass index (BMI - kg/m^2)	26.6 (23.9-29.9)	26.6 (23.4-29.8)	0.66
Abdominal girth/height	0.58 (0.55-0.65)	0.58 (0.53-0.62)	0.28
Mean pulmonary artery pressure (mm Hg)	24 (20-30)	24 (20-30)	0.71
Lung allocation score	40.64 (36.38-47.90)	38.28 (34.37-43.45)	**< 0.01**
Six minute walk distance pretransplant (ft)	930 (750-1109)	1060 (801-1211)	**< 0.01**
Pre-transplant hospital length of stay (days)	1 (0-2)	1 (0-1)	0.35
ECMO as bridge to transplant	8 (9%)	5 (3%)	0.14
CMV mismatch (D+/R−)	22 (23%)	38 (26%)	0.34
Donor variables			
Donor age (years)	31 (23-40)	30 (23-38)	0.31
Donor-recipient sex mismatch	23 (24%)	29 (20%)	0.43
HLA A+B+DR mismatch	5 (4-5)	5 (4-5)	0.53
Donor-recipient pTLC ratio	1.06 (0.97-1.15)	1.06 (0.95-1.12)	0.43
Donor diabetes	9 (10%)	5 (3%)	0.09
Donor smoking > 20 pack years	15 (16%)	10 (7%)	**0.03**
Ex-vivo lung perfusion (EVLP)	20 (21%)	15 (10%)	**0.03**
Donor ischemic time (hours)	6.05 (5.05-7.55)	5.63 (4.68-6.37)	**< 0.01**
Donor-derived *Staphylococcus aureus*	35 (37%)	53 (37%)	1.00
Donor-derived Gram-negative rods	21 (23%)	39 (27%)	0.54
Donor-derived yeast	12 (13%)	25 (17%)	0.46
Intraoperative and postoperative variables			
Intra-operative transfusion (units)			
Packed red blood cells	4 (2-6)	2 (1-4)	**< 0.01**
Fresh frozen plasma	3 (1-6)	1 (0-3)	**< 0.01**
Platelets	0 (0-2)	0 (0-1)	**< 0.01**
Cryoprecipitate	0 (0-1)	0 (0-0)	**< 0.01**
Intraoperative cardiopulmonary support	73 (78%)	102 (71%)	0.29
Intra-operative colloid (liter)	0.75 (0.25-1.25)	0.75 (0.25-1.00)	0.64
Intra-operative crystalloid (liter)	2.05 (1.25-3.50)	2.50 (1.50-3.50)	0.23
Primary graft dysfunction grade at time zero			**< 0.01**
0	0	0	
1	21 (22%)	52 (36%)	
2	17 (18%)	52 (36%)	
3	56 (60%)	40 (28%)	
Comatose (RASS= −4 or −5) on POD#2	43 (46%)	3 (2%)	**< 0.01**

Abbreviations: CMV, cytomegalovirus; ECMO, extracorporeal membrane oxygenation; POD, post-operative day; pTLC, predicted total lung capacity; RASS, Richmond Agitation and Sedation Scale.

Bold highlights significant values.

6), $p < 0.01$] and hospital LOS [24.5 days (IQR 18-44) vs 13 days (IQR 11-18), $p < 0.01$]. Extubation failure was also associated with greater need for inpatient rehabilitation (32% vs 8%, $p < 0.01$). Survival at 30 days postoperatively was 97% in patients with extubation failure vs 99% in those successfully extubated ($p = 0.30$). On the other hand, 6-month Kaplan-Meier survival was significantly different between those with extubation failure vs success (87% vs 98%, $p < 0.01$, see Figure 2).

We sought to determine whether there were risk factor and outcome differences between the subcategories of extubation failure. Compared to patients with successful extubation, those requiring endotracheal intubation > 3 days or reintubation received greater intraoperative blood products. Patients requiring tracheostomy had increased donor smoking incidence, postoperative PGD, and intraoperative PRBC needs (see Figure S1). Patients that were reintubated or underwent tracheostomy

Table 2 Multivariate Analysis of Risk Factors for Extubation Failure

Risk Factor	Odds ratio	95%CI	*p*-value
Comatose (RASS= −4 or −5) on POD#2	84.95	17.06-423.03	**< 0.01**
Donor smoking > 20 pack years	5.41	1.73-16.92	**< 0.01**
PGD grade at time 0 hour	2.02	1.22-3.34	**< 0.01**
Intraoperative PRBCs	1.19	1.06-1.34	**< 0.01**
Recipient female sex	1.69	0.51-5.62	0.39
Ischemic time (hours)	1.07	0.83-1.39	0.60
Six-minute walk distance (feet)	1.00	0.99-1.00	0.15
Lung allocation score	1.00	0.97-1.03	0.88
Recipient height	0.96	0.91-1.03	0.27
Ex-vivo lung perfusion	1.19	0.06-22.66	0.91

Abbreviations: CI, confidence interval; PGD, primary graft dysfunction; POD, post-operative day; PRBCs, packed red blood cells; RASS, Richmond Agitation and Sedation Scale.
Bold highlights significant values.

Table 3 Short-Term Outcomes Based on Extubation Success

Outcome	Total cohort (N = 238)	Extubation failure (N = 94)	Extubation success (N = 144)	*p*-value
PGD grade 3 at 72 hours	46 (19%)	35 (37%)	11 (8%)	**< 0.01**
Post-transplant ECMO	53 (22%)	46 (49%)	7 (5%)	**< 0.01**
Tracheostomy	75 (32%)	75 (80%)	N/A	
Time to tracheostomy (days)	3 (2-4)	3 (2-4)	N/A	
Tracheostomy duration (days)	17 (12-36)	17 (12-36)	N/A	
Intensive care unit length of stay (days)	6 (4-13)	14 (10-26)	4 (4-6)	**< 0.01**
Hospital length of stay (days)	17 (12-25)	25 (18-44)	13 (11-18)	**< 0.01**
Discharge disposition				**< 0.01**
Local housing	191 (80%)	59 (63%)	132 (92%)	
Inpatient rehab	41 (17%)	29 (32%)	12 (8%)	
Death	6 (3%)	6 (6%)	0	
Number of readmissions (30-days postindex discharge)	0 (0-1)	0 (0-1)	0 (0-1)	0.68
30-day mortality	4 (1.7%)	3 (3%)	1 (0.7%)	0.30
6-month mortality	15 (6%)	12 (13%)	3 (2%)	**< 0.01**

Abbreviations: ECMO, extracorporeal membrane oxygenation; PGD, primary graft dysfunction.
Bold highlights significant values.

experienced greater ICU LOS than those that were successfully extubated [reintubation median 9 days (IQR 9-11), reintubation + tracheostomy median 17.5 days (IQR 2.3-19.8), empiric tracheostomy median 17.5 days (IQR = 12-36.5) vs successful extubation median 4 days (IQR 4-6)]. A similar pattern was evidenced regarding hospital LOS [reintubation median 20 days (IQR 17-25), reintubation + tracheostomy median 28 days (IQR 23-50), empiric tracheostomy median 28.5 days (IQR 20-48.25) vs successful extubation median 13 days (IQR 11-18). Additionally, patients undergoing tracheostomy had significantly greater inpatient rehabilitation needs following the index hospitalization (reintubation + tracheostomy = 32%, empiric tracheostomy = 38%, successful extubation = 8%, $p < 0.01$, Figure 3). Finally, there was a significant difference in 6-month mortality between patients requiring empiric tracheostomy and patients successfully extubated, but no mortality differences between other subgroups (21% vs 3% $p < 0.01$) (Figure 2).

We also assessed functional differences in patients with extubation failure using the baseline 6MWD assessed at the initial mandatory ambulatory pulmonary rehabilitation session (Figure 4). Patients requiring tracheostomy had significantly delayed initial rehabilitation sessions compared to patients extubated successfully. Time to first pulmonary rehabilitation appointment was a median 19 days (IQR 14-28) for those who were successfully extubated, 35 days (IQR 27-59.5) for patients that underwent reintubation + tracheostomy, and 46 days (IQR 26-80) for those with empiric tracheostomy ($p < 0.01$ for both). The initial posthospitalization 6MWD was 940 ft (IQR 740-1210) for patients successfully extubated vs 740 ft (IQR 530-950) for those reintubated + tracheostomy and 655 ft (IQR 490-960) for those with empiric tracheostomy. There were no significant differences in time to the initial ambulatory rehabilitation appointment or 6MWD in patients with prolonged endotracheal tube intubation or those reintubated after failed extubation.

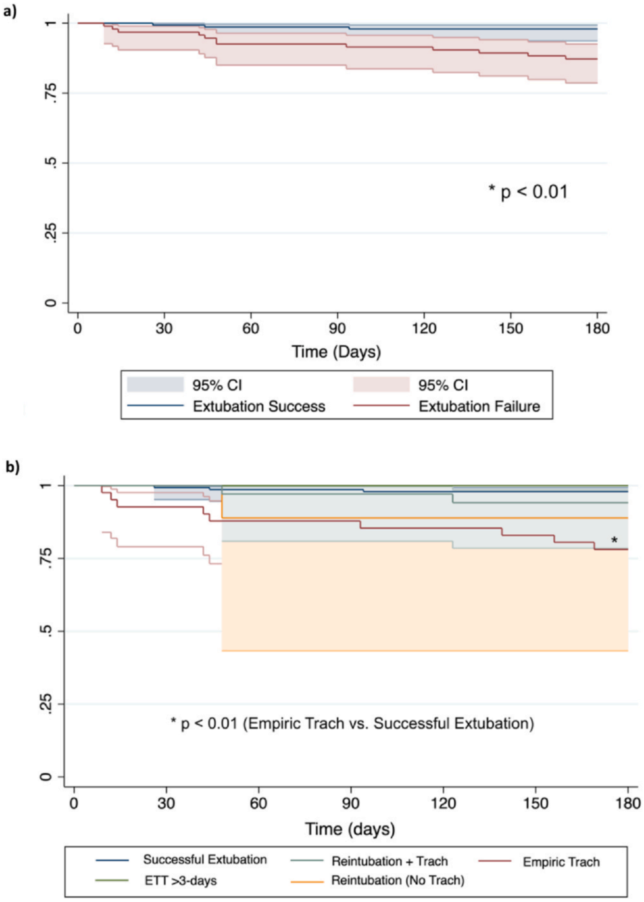

Figure 2 Kaplan-Meier 6-month survival by extubation failure vs success. Six-month post-transplant survival is depicted using the Kaplan-Meier estimate. **(a)** Six-month survival was 87% in patients with extubation failure vs 98% in patients with extubation success ($p < 0.01$). **(b)** Six-month survival based on subgroup analysis of different types of extubation failure (where ETT > 3 days is patients extubated after 3 days). There is a significant difference between patients that were successfully extubated and those that underwent empiric tracheostomy via Kruskal-Wallis testing and subsequent pair-wise analysis ($p < 0.01$). There were no other statistically significant differences between classes of extubation failure. ETT, endotracheal tube.

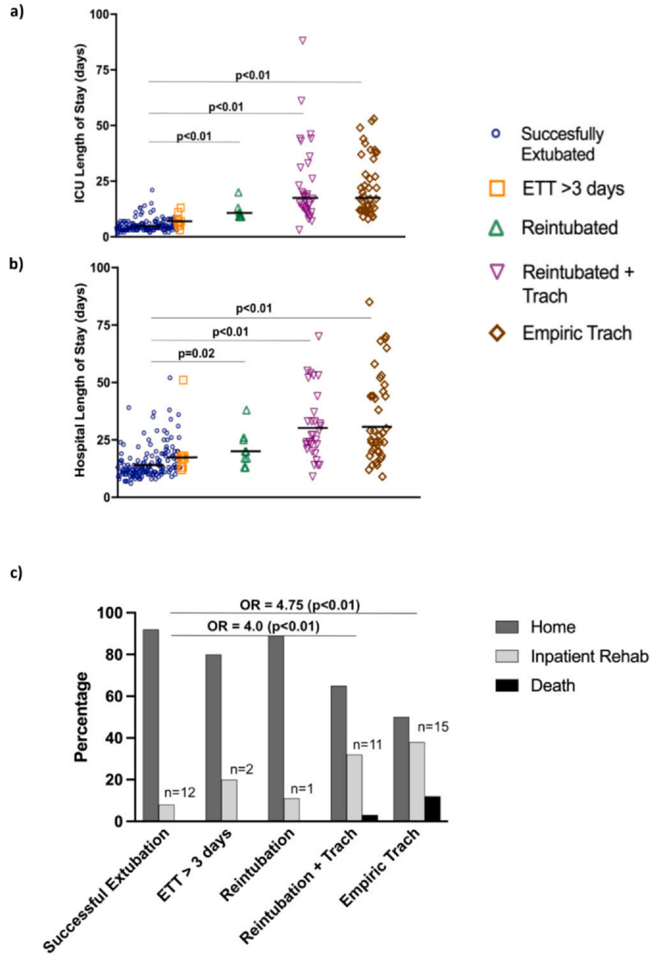

Figure 3 Short-term outcomes by extubation subgroup: short-term outcomes were compared using Kruskal-Wallis testing with posthoc Dunn's testing. Patients requiring reintubation, reintubation with tracheostomy, or empiric tracheostomy were associated with increased ICU length of stay **(a)** and hospital length of stay **(b)** compared to patients successfully extubated. **(c)** Disposition was compared for subgroups using Fisher testing with posthoc pairwise analysis. Tracheostomy was associated with increased need for inpatient rehabilitation post index hospitalization.

Discussion

This large, single-center retrospective study identifies risk factors associated with extubation failure, defined broadly as patients with endotracheal intubation > 3 days and need for reintubation and/or empiric tracheostomy. On univariate and multivariate regression analysis, deep sedation on postoperative day#2, donor smoking history, female sex, PGD, and increased transfusion needs were associated with extubation failure. We also demonstrated that patients with extubation failure, especially those requiring reintubation and/or tracheostomy, experienced worse short-term outcomes including increased ICU and hospital LOS, greater need for inpatient rehabilitation, and increased 6-month mortality.

Our study highlights several novel associations with extubation failure not shown in prior studies. First, we show that donor smoking history of > 20 pack-years is linked to extubation failure. The underlying pathophysiology of this is unclear. While donor smoking history was recently shown to not be a risk factor for PGD in a large single-center retrospective study, it did increase the risk of allograft dysfunction and mortality.[18] Interestingly, lungs from donors that actively smoked prior to death were associated with a mild increase in PGD, suggesting a possible mechanism between tobacco use and allograft dysfunction.[19] Also of interest is that PRBC transfusion, but not crystalloid or albumin, was a risk factor for extubation failure, even when controlling for PGD at time 0 and total ischemic time. It is possible that transfusion needs reflect difficult native lung dissections, which may lead to increased pain and time to recovery post-transplant.[20] Blood product transfusion also leads to release of cell-free hemoglobin, which has been shown to drive PGD after lung transplantation and cause oxidant-mediated endothelial injury.[21] We expected frailty to be a marker of risk for extubation failure;

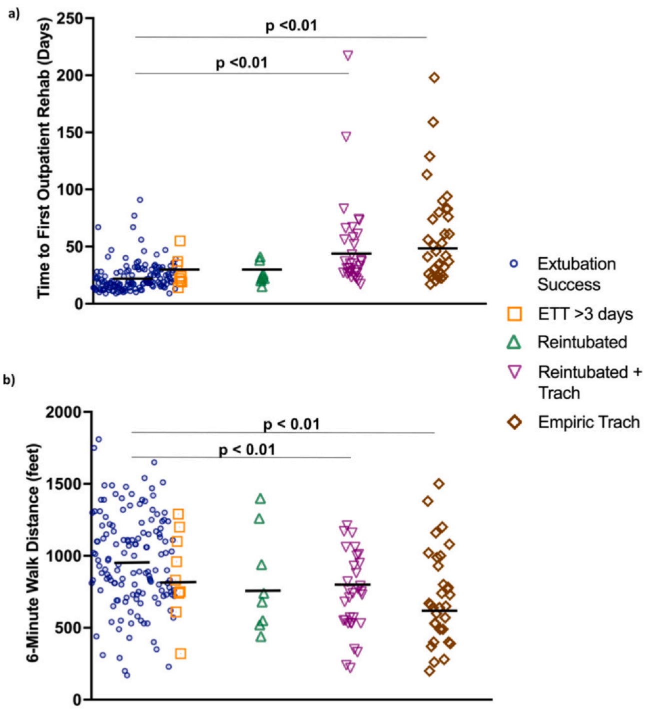

Figure 4 Functional outcomes in patients with extubation failure. Time to first ambulatory rehabilitation appointment and initial 6MWD at that appointment are displayed below. Differences between extubation subgroups were assessed via Kruskal-Wallis testing and posthoc Dunn analysis. **(a)** Time to first rehab appointment was a median 20 days (IQR 15-29) for those who were successfully extubated, 35 days (IQR 27-59) for patients that underwent reintubation + tracheostomy, and 42 days (IQR 26-80) for those with empiric tracheostomy ($p < 0.01$ for both). **(b)** Initial posthospitalization 6MWD was 930 ft (IQR 730-1200) for patients successfully extubated vs 740 ft (IQR 540-940) for those reintubated + tracheostomy and 665 ft (IQR 520-945) for those with empiric tracheostomy. IQR, interquartile range.

however, frailty proxies, such as six-minute walk distance and age, did not correlate with extubation failure in this analysis. Surprisingly, BMI and abdominal girth/height ratio, native lung disease, and single vs bilateral lung transplantation were also not associated with extubation failure, despite the expectation that these conditions might affect chest wall mechanics. The lack of an association between body morphology and extubation success lends further credence to the fact that BMI and other measures should not exclusively be used to limit candidacy for lung transplantation.

We performed this analysis to analyze whether pragmatic airway management influenced short-term outcomes in lung transplant recipients and to identify recipient, donor, and intraoperative characteristics associated with extubation failure. This information might be useful to guide future studies regarding optimal timing of tracheostomy posttransplant; timely tracheostomy might facilitate achievement of recovery milestones. Our findings suggest that there may be clinical equipoise between a trial of extubation and empiric tracheostomy, as short-term outcomes are similar between these groups. Future, well-designed prospective studies are needed to solidify our understanding of the impact of early airway management strategies.

There are several strengths to our study. Our cohort demographics and contemporary management practices represent those of large-volume transplant centers in North America. Our analyses included clinically relevant donor and recipient variables that we and others considered important to extubation success, such as ischemic time, EVLP, intraoperative transfusion, body morphology, and surrogates of frailty (pretransplant hospitalization, pretransplant ECMO, 6MWD); the contribution of some of these variables on extubation success has not been previously assessed. Our definition of extubation failure was clinically pragmatic and included prolonged intubation and need for reintubation, conditions that have not been considered in prior studies. Our study had several limitations. The retrospective nature precluded inclusion of objective measures of variables that can affect extubation outcomes, such as frailty, pain, glycemic control, delirium, and ambulation. Moreover, we were unable to incorporate predetermined criteria for certain endpoints, such as indications for tracheostomy, which increases variability. This study is single-center and cannot account for regional variations in surgical technique and medical management that can influence outcomes. Additionally, our study is prone to confounding bias related to the interdependence of several variables. Finally, it is unclear whether efforts to further reduce tracheostomy time would lead to improved outcomes.

Conclusion

In conclusion, we demonstrate that patients failing extubation, especially those requiring tracheostomy, are more likely to have increased index hospital length of stay, need for inpatient rehab, and significantly worse 6-month survival. Moreover, donor smoking history, female sex, PGD, greater intraoperative red cell transfusion needs, and increased ischemic time are all associated with extubation failure. These data help identify patients who may have increased risk for extubation failure; future studies should focus on optimal management to reduce resultant morbidity.

Disclosure statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.jhlto.2023.100046.

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