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Peri-intubation adverse events and clinical outcomes in emergency department patients: the BARCO study

Ian Ward A. Maia[1,2*], Bruno A. M. Pinheiro Besen[3], Lucas Oliveira J. e Silva[2,4], Rafael von Hellmann[5], Ludhmila Abrahao Hajjar[1], Benjamin J. Sandefur[2], Daniel Fontana Pedrollo[4], Caio Goncalves Nogueira[6], Natalia Mansur P. Figueiredo[6], Carlos Henrique Miranda[7], Danilo Martins[8], Thiago Dias Baumgratz[8], Bruno Bergesch[9], Diogo Costa[9], Osmar Colleoni[10], Juliana Zanettini[11], Ana Paula Freitas[11], Nicole Pinheiro Moreira[12], Patricia Lopes Gaspar[12,13], Renato Tambelli[14], Maria Cristina Costa[15], Samara Silveira[15], Wilsterman Correia[16], Rafael Garcia de Maria[17], Ubirajara A. Vinholes Filho[18], Andre P. Weber[19], Vinicius da Silva Castro[20], Carlos Fernando D. Dornelles[21], Barbara S. Tabach[21], Hélio P. Guimarães[1], Gabriela Stanzani[1], Thiago F. Gava[1], Aidan Mullan[2], Heraldo P. Souza[1], Otavio T. Ranzani[22,23], Fernanda Bellolio[2], Julio C. G. Alencar[24], on behalf BARCO group, Victor Paro da Cunha, Julio F. Marchini, Patricia Albuquerque Moura, Fernanda Greco, Yasmine Filippo, Rubens Yoshinori Kai, Guilherme Torres Abi Ramia Chimelli, Juan Valdivia, Edson Luiz Favero Junior, Felipe Rischini, Vitor Amorim de Andrade Câmara, Henrique Bertotto, Victor Borges, Juliano Rathke, Renato Melo, Ariadine Augusta Maiante, Sarah Maciel Silva, Clarisse Moreira Ribeiro de Oliveira, Andressa Pi Rocha Reis, Thamyres de Carvalho Rufato, Gabriella Dias, Victoria Sartor Poloni, Kauê Lima, Hilana Zenly, José Carlos Motta, Gabriel Miranda, Alexandre Freitas, Leonardo Gasperini, Thais Raimondi Sudbrack, Ana Paula Ribeiro, Guilherme Henrique A. do Carmo, Andrea de Vargas Tomelero, Augusto Lengler Konrath, Vitor Cremonese Zanella, Natalia Fuhr, Davi Amaral Cesário Rosa, Isabela Lopes Lima, Luiz Fernando Varela, Isabella Baldino, Andre Zimmerman, Julia M. Dorn de Carvalho and Molly M. Jeffrey

*Correspondence:
Ian Ward A. Maia
ian.ward.maia@gmail.com
Full list of author information is available at the end of the article

Abstract

Background Emergency tracheal intubation in critically ill patients carries a high risk of complications, and practices vary substantially across different settings. Identifying risk factors and understanding how peri-intubation adverse events affect patient outcomes may guide standardization of care and improve survival.

Methods This prospective cohort study involved 18 emergency departments in Brazil (March 2022–April 2024). We included adults (≥ 18 years) undergoing emergency intubation and excluded patients intubated electively or for cardiac arrest. We defined major peri-intubation adverse events as severe hypoxemia, new hemodynamic instability, or cardiac arrest occurring within 30 min of initiating intubation. The primary outcome was 28-day mortality. Multivariable regression analyses assessed associations between adverse events and mortality, controlling for potential confounders.

Results Among 2846 patients, major adverse events occurred in 919 (32.3%) intubations, most frequently new hemodynamic instability (20.0%), followed by severe hypoxemia (12.5%) and cardiac arrest (3.5%). The overall 28-day mortality was 45.1%. Patients experiencing any major adverse event had a significantly higher 28-day mortality (57.6 vs 39.2%; aHR 1.43, 95% CI 1.26–1.62; $p < 0.001$). Sensitivity analyses confirmed these findings. Successful first-attempt intubation was associated with a reduced likelihood of major adverse events (aOR 0.52; 95% CI 0.41–0.65; $p < 0.001$).

Conclusion One in three patients undergoing emergency intubation experienced a major peri-intubation adverse event, which was associated with higher 28-day mortality. These results underscore the importance of optimizing intubation strategies to reduce complications and potentially improve patient outcomes in critically ill patients.

Keywords Intubation, Airway registry, Difficult airway, Adverse events, Critical illness, Emergency airway management

Background

Tracheal intubation (TI) is a critical procedure performed in emergency departments (EDs) and intensive care units (ICUs) worldwide [1]. While essential for managing critically ill patients, it carries significant risks, particularly in resource-limited settings [1–3]. Major adverse events (MAEs), such as hemodynamic instability, severe hypoxemia, and cardiac arrest, are frequently observed in the peri-intubation period and have been associated with worse patient outcomes [3–6].

Critically ill patients frequently present with a 'physiologically difficult airway,' characterized by acute hemodynamic instability, compromised oxygenation, and metabolic disturbances that increase the risk of peri-intubation adverse events, even in the absence of anatomical airway difficulty [7, 8]. An international cohort study involving 29 countries found that the incidence of MAEs during emergency intubations exceeded 40% [4]. The study reported a first-attempt intubation success rate of nearly 80%, with only 4.5% of patients requiring more than two attempts. This high incidence of MAEs, despite relatively high first-attempt success, suggests that factors beyond anatomic challenges contribute to adverse events [4, 9–11].

Understanding potential causal pathways in airway management is crucial for improving outcomes in critically ill patients undergoing emergency intubations globally [12–14]. However, the global burden of these complications remains poorly understood in low- and middle-income countries (LMICs), since prospective studies examining the association between peri-intubation adverse events and 28-day mortality are limited [4–6].

Therefore, we established the Brazilian Airway Registry Cooperation (BARCO), the first multicenter registry of emergency intubations in a middle-income country. This study aims to determine the incidence of MAEs and their association with 28-day mortality in critically ill patients undergoing emergency intubations, offering essential data from a resource-limited setting.

Methods

Study design and setting

We conducted a prospective cohort study across 18 EDs in Brazil, spanning four regions, as part of the BARCO network. We report these results in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement [15]. This study was approved by the ethics committees of all participating centres. Due to the observational nature of the study and the use of de-identified data, a waiver of individual patient consent was granted by each institution's ethics committee.

Participants

We enrolled adults (age ≥ 18 years) undergoing TI in the ED. Exclusion criteria were intubations performed for elective procedures or during cardiac arrest. Tracheal

intubations were performed by clinical staff working in the ED. Specific procedural aspects, including the choice of medications, equipment, and intubation techniques, were determined according to clinicians preferences and standard practices at each participating center. To ensure comprehensive data collection and avoid selective reporting, each site investigator submitted a study compliance plan approved by the coordinating center (Hospital das Clínicas de São Paulo, SP, Brazil). This plan detailed the process for identifying consecutive ED intubations and ensuring at least 80% were recorded in the BARCO database. Monthly compliance reports were submitted and reviewed by BARCO coordinators for quality control.

Exposures and outcomes

Our primary exposures were MAEs, defined as the presence of one or more of the following within 30 min from the start of the intubation procedure: severe hypoxemia (peripheral oxygen saturation < 80%), new hemodynamic instability (systolic arterial pressure < 65 mmHg recorded at least once, new requirement for or increase the dose of vasopressors, or administration of a fluid bolus > 15 mL/kg to maintain target blood pressure), or cardiac arrest [4]. Our primary outcome was 28-day mortality after TI, assessed through electronic health record reviews, with follow-up until hospital discharge, death, or 28 days, whichever occurred first. Secondary outcomes included the incidence of MAEs, difficult intubations (defined as three or more attempts), the first-attempt success, transient hypotension, defined as a single episode of systolic blood pressure < 90 mmHg or mean arterial pressure < 65 mmHg that does not fulfill the criteria for new hemodynamic instability, and esophageal intubation.

Data collection

Intubation observers completed a structured, web-based data collection form using a survey on REDCap®. [16, 17] We required the form to be completed within 30 min of tracheal intubation confirmation. A site investigator at each center trained staff on completing the form and designated a trained observer rather than the clinician who performed the intubation to complete the form.

We collected variables representing patient characteristics, illness severity, preprocedural physiology, and intubation characteristics. Definitions for all collected variables are available in eMethods1. (Appendix File).

Statistical analysis

As this study was designed to be a prospective observational airway management registry, we did not calculate a target sample size. Given the inclusion of 18 centers with a minimum of 40 intubations to be included, the minimum sample size would be 720 intubations, but we estimated that 3–5 times more participants would be included given the center's volumes of inclusion, which would allow sufficient power to estimate the rate of adverse events, 28-day mortality and to explore their association.

We present descriptive statistics as mean ± SD or median (interquartile range [IQR]) for continuous variables, frequency and proportion for categorical variables, stratified by peri-intubation MAEs. We performed bivariate analyses with χ^2 or Fisher's exact test for categorical variables, and the Mann–Whitney or t-test for continuous variables, as appropriate. We plotted the 28-day survival with a Kaplan–Meier survival curve, stratified by each combination of MAEs. Patients transferred or with unknown outcome were excluded from survival analysis.

We utilized Cox proportional hazards models to assess the association between the occurrence of MAEs and 28-day mortality. Recognizing that adverse events during emergency intubations and 28-day mortality may have shared underlying causes, we identified potential confounders using a directed acyclic graph (DAG) (Supplemental eFigure 3). This method allowed us to account for causal pathways while avoiding mediators, open backdoor paths, and collider bias [18]. The Cox model accounted for clustering with center-specific shared frailties.

We developed three models: (1) an unadjusted model, (2) a model adjusted for patient characteristics and preprocedural physiology (age, sex, BMI, Charlson comorbidity score, shock index, SOFA score, and pre-intubation SpO_2), and (3) a model adjusted for patient characteristics, preprocedural physiology and intubation characteristics (first-attempt success, Cormack-Lehane classification, subjective impression of difficulty, and use of intubation drug agents such as analgesics, hypnotics, and paralytics). We report hazard ratios (HRs) with 95% confidence intervals (CIs) for these analyses. In the main analysis, patients discharged home were assumed to be alive at 28 days.

We performed sensitivity analyses for the Cox model to account for potential informative censoring. We analyzed the results with (a) a logistic regression model using in-hospital mortality as the outcome, (b) a Cox model censoring patients at hospital discharge, (c) a Fine and Gray model accounting for hospital discharge as a competing outcome, and (d) a worst-case scenario analysis. Furthermore, we performed sensitivity analyses for unmeasured confounding with E-values, which evaluate the strength of the association of an unknown confounder that would neutralize the observed associations [19].

We performed supplemental exploratory analyses to identify factors associated with first-attempt success and the incidence of MAE (Supplemental eMethods

3). Additionally, we assessed the association between first-attempt success and the number of intubation attempts with MAE.

All statistical tests were two-sided, and p-values less than 0.05 were considered significant. All analyses were conducted using R version 4.2.2 and Stata SE 18.0.

Results

From March 1, 2022, to April 30, 2024, we enrolled patients at 18 EDs, 4 community and 14 academic hospitals (eTable 1, Appendix File). We screened 3618 patients who underwent TI during the 2-year study period, of whom 2846 were included in the final analysis (Fig. 1). Additional details on enrollment numbers by centers characteristics, and missing intubation data are described in Supplement eTables 1 and Fig. 1, respectively.

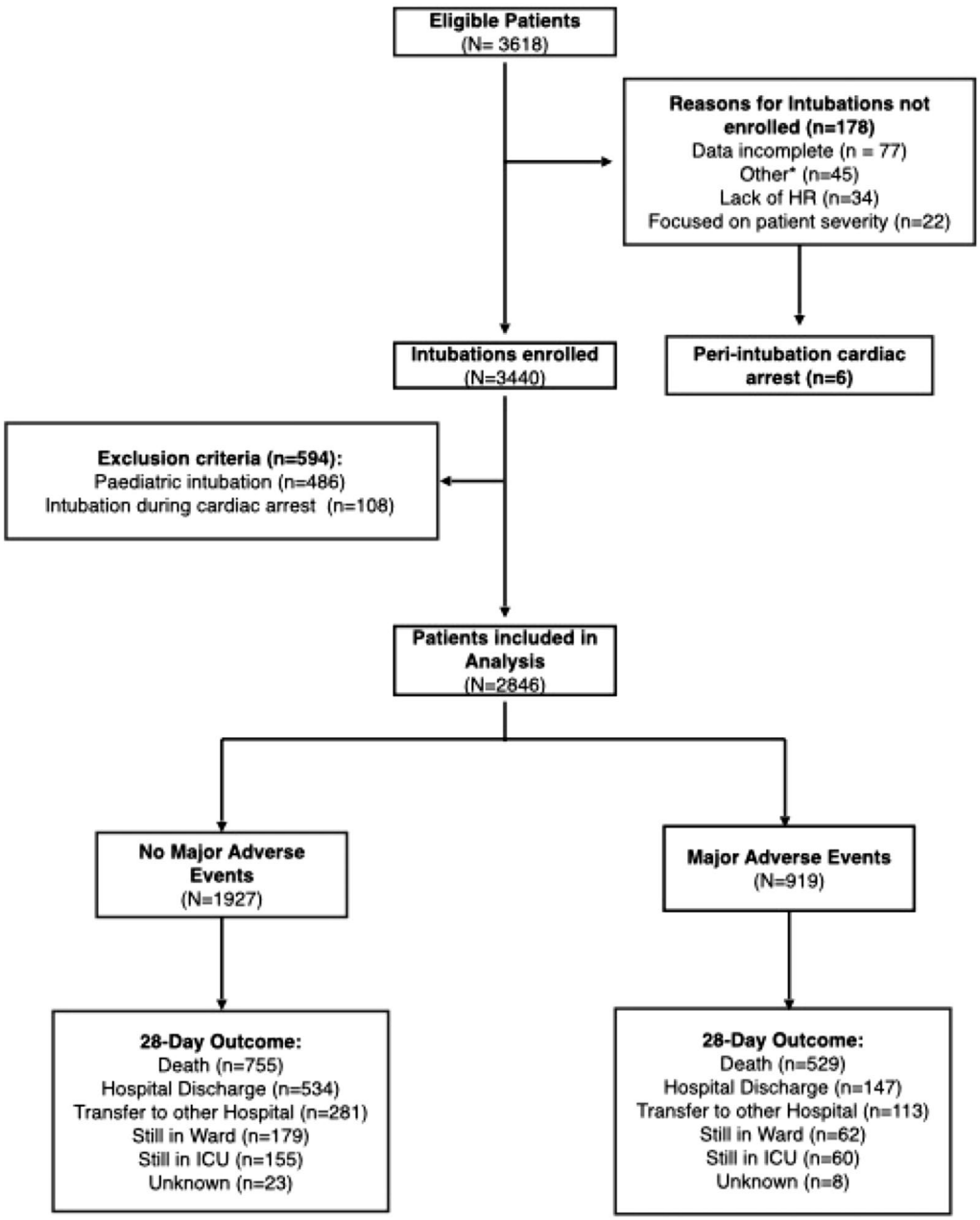

Fig. 1 Enrollment flow diagram. *Others reasons for no inclusion intubations were "forgot to fill out", "doesn't remember completing", or "invalid record number"). HR: Health Records; ICU: Intensive Care Unit

Patient baseline characteristics

The median age was 63 years (IQR, 49–73), and most were male (58.0%). Patients who experienced MAEs were older (median age 65 vs 62 years; $p < 0.001$), had a higher pre-intubation shock index (0.87 vs 0.74; $p < 0.001$), and were more likely to have been intubated for acute respiratory failure (47.9% vs 30.6%, $p < 0.001$). Table 1 and eTable 2 detail the characteristics of included patients.

Intubation characteristics

First-attempt success occurred in 2116 (74.3%) cases. Direct laryngoscopy (DL) was used for the first intubation attempt in 2294 (80.6%) cases (Table 1). The median number of attempts was 1 (IQR, 1–2), with difficult intubations occurring in 198 (7.0%) patients. Pre-treatment with fentanyl was used in 630 (22.1%) intubations. Etomidate was the most used induction agent ($n = 1655$ [58.2%]), followed by ketamine ($n = 751$ [26.4%]). Propofol was rarely used ($n = 89$ [3.1%]). Rapid sequence intubation (RSI) was employed in 2462 (86.5%) of the intubations. Residents in Emergency Medicine and Internal Medicine performed the first intubation attempt in 1097 (38.5%) and 1125 (39.5%) cases, respectively. As first operators, anesthesiologists participated in only 3 intubations (0.1%). First-year residents were the first operators in 1351 (47.5%) cases. A surgical airway was performed on only 1 (0.04%).

Incidence of MAEs

Of 2846 patients, 919 (32.3%) experienced at least one MAEs. New hemodynamic instability was the most common MAE (569, 20.0%), followed by severe hypoxemia in 356 (12.5%) intubations, and peri-intubation cardiac arrest in 100 (3.5%) intubations, with 73 (73.0%) of these achieving the return of spontaneous circulation. Table 2 presents other complications. At least one episode of transient hypotension occurred in 345 (12.1%) intubations, and esophageal intubation was reported in 86 (3.0%) intubations.

Association of MAEs with 28-day mortality

Overall, 28-day mortality was 45.1%. Mortality was higher among patients experiencing MAEs compared to those who did not (57.6 vs 39.2%, $p < 0.001$). Figures 2 and 3 presents the association of MAEs and their subcomponents with 28-day mortality. MAEs were associated with increased 28-day mortality (aHR 1.43, 95% CI 1.26–1.62, $p < 0.001$). All subcomponents were also associated with increased 28-day mortality, including increased HR from hemodynamic instability (aHR 1.28, 95% CI 1.11–1.48, $p < 0.001$) followed by severe hypoxemia (adjHR 1.39, 95% CI, 1.16–1.66, $p < 0.001$) and cardiac arrest (aHR 2.52, 95% CI 1.86–3.40, $p < 0.001$). Finally, patients experiencing both hemodynamic instability and severe hypoxemia had an increased risk of mortality compared to those with neither (aHR 1.97, 95% CI 1.38–2.81, $p < 0.001$, Appendix file, eTable 7), which was higher than either hemodynamic instability or severe hypoxemia alone.

All sensitivity analyses to the Cox model assumptions demonstrated similar results (Fig. 2 and Appendix, eTables 8–11), suggesting the robustness of model assumptions. E-values for the point estimate and its lower confidence interval were, respectively, 1.88 and 1.63 for all MAEs; 1.66 and 1.36 for hemodynamic instability; 1.82 and 1.45 for severe hypoxemia; and 3.18 and 2.44 for cardiac arrests (Appendix file, eFigures 4–7).

Factors associated with MAEs and first-attempt success

Patients who experienced MAEs had lower observed first-attempt success (66.3% vs 78.2%, $p < 0.001$). Successful first-attempt intubation was associated with a lower likelihood of experiencing MAEs (aOR 0.52, 95% CI 0.41–0.65, $p < 0.001$), while each additional attempt was associated with higher odds of MAEs (aOR 1.65, 95% CI: 1.45–1.88, $p < 0.001$; Appendix file, eTable 5). Moreover, each additional intubation attempt markedly increased the risk of severe hypoxemia (aOR 2.28, 95% CI 1.95–2.65, $p < 0.001$, eTable 5). Increasing age, elevated shock index, higher SOFA score, lower pre-intubation oxygen saturation, and acute respiratory failure as an indication for intubation were significantly associated with peri-intubation MAEs in the multivariable analysis (Table 3). Performing an intubation checklist was significantly protective against peri-intubation MAEs (aOR, 0.75; 95% CI 0.57–0.98; $p = 0.036$). Patients receiving ketamine experienced a higher unadjusted rate of MAEs compared to those receiving etomidate (29.8 vs 24.8%, $p < 0.001$), however, no significant difference in MAEs was observed among different induction agents in multivariable analysis (Table 3). The specialty of the first operator was associated with first-attempt success, with internal medicine (OR 0.61, 95% CI 0.44–0.83, $p = 0.002$) specialists having lower odds of first-attempt success compared to emergency medicine specialists. Intubation with a bougie was associated with higher odds of first-attempt success (OR 1.57, 95% CI 1.06–2.34, $p = 0.025$, eTable 6).

Discussion

In this multicenter prospective cohort study of critically ill adults undergoing emergency tracheal intubation, MAEs occurred in 32.3% of patients: hemodynamic instability, in 20.0%; severe hypoxemia, in 12.5%; and cardiac arrest, in 3.5%. The overall 28-day mortality was 45.1%. Patients who experienced MAEs had significantly higher mortality, even after adjustment for patient-level

Table 1 Patient demographics and intubation characteristics

	All patients (N = 2846)	Major Adverse event (N = 919)	No major events (N = 1927)	*p*-value
Patient Characteristics				
Age, years, median (IQR)	63 (49, 73)	65 (51, 75)	62 (47, 72)	< 0.001
Sex, male, n (%)	1652 (58%)	543 (59.1%)	1109 (57.6%)	0.44
BMI, kg/m^2, median (IQR)	25.7 (23.4, 27.8)	25.7 (23.4, 27.8)	25.7 (23.4, 27.8)	0.74
Data available, n (%)	2823 (99.2%)	912 (99.2%)	1911 (99.2%)	
Mean arterial pressure, mmHg, median (IQR)	96.7 (80, 113.3)	89.8 (76, 106.7)	99.3 (83.3, 116.7)	< 0.0001
Data available, n (%)	2764 (97.1%)	876 (95.3%)	1888 (98%)	
Shock index, median (IQR)	0.78 (0.61, 0.99)	0.87 (0.68, 1.08)	0.74 (0.58, 0.93)	< 0.0001
Data available, n (%)	2756 (96.8%)	873 (95%)	1883 (97.7%)	
Charlson comorbidity index, 0–37, median (IQR)	3 (1, 5)	3 (2, 5)	3 (1, 5)	< 0.0001
SOFA score*, 0–24, median (IQR)	4 (3, 6)	4 (3, 7)	4 (2, eh)	< 0.0001
Hemodynamic resuscitation preintubation, n (%)				
Fluids[a]	616 (21.6%)	246 (26.8%)	370 (19.2%)	< 0.0001
Vasopressors[b]	831 (29.2%)	331 (36%)	500 (25.9%)	< 0.0001
Blood transfusion	65 (2.3%)	31 (3.4%)	34 (1.8%)	
Intubation Characteristics				
Indication for intubation, n (%)				< 0.0001
Airway protection	1292 (45.4%)	310 (33.7%)	982 (51.0%)	
Acute respiratory failure	1029 (36.2%)	440 (47.9%)	589 (30.6%)	
Anticipation of clinical course	449 (15.8%)	151 (16.4%)	298 (15.5%)	
Transport risk	13 (0.5%)	1 (0.1%)	12 (0.6%)	
Not recorded	63 (2.2%)	17 (1.8%)	46 (2.4%)	
Primary diagnosis of trauma, n (%)	222 (7.8%)	55 (6.0%)	167 (8.7%)	0.013
Subjective impression of difficult intubation[c], n (%)	762 (26.8%)	287 (31.2%)	475 (24.6%)	< 0.0001
Time between indication and intubation**, n (%)				0.026
0–15 min	1430 (50.2%)	424 (46.1%)	1006 (52.2%)	
15–60 min	1189 (41.8%)	414 (45%)	775 (40.2%)	
> 60 min	222 (7.8%)	79 (8.6%)	143 (7.4%)	
Unknown timing	5 (0.2%)	2 (0.2%)	3 (0.2%)	
Institutional checklist performed prior to intubation, n (%)				0.011
No	1593 (56.0%)	546 (59.4%)	1047 (54.3%)	
Yes	1253 (44%)	373 (40.6%)	880 (45.7%)	
Preoxygenation method, n (%)				
Non-invasive ventilation	353 (12.4%)	134 (14.6%)	219 (11.4%)	
Non-rebreathing mask	870 (30.6%)	252 (27.4%)	618 (32.1%)	
Bag-Valve-Mask	1514 (53.2%)	498 (54.2%)	1016 (52.7%)	
High-flow nasal catheter	47 (1.7%)	10 (1.1%)	37 (1.9%)	
Other preoxygenation	35 (1.2%)	12 (1.3%)	23 (1.2%)	
No preoxygenation	26 (0.9%)	13 (1.4%)	13 (0.7%)	
Not recorded	1 (0%)	0 (0%)	1 (0.1%)	
SpO_2 measured before intubation, %	99 (95, 100)	97 (92, 100)	99 (96, 100)	< 0.0001
Intubation method, n (%)				0.28
RSI	2389 (83.9%)	758 (82.5%)	1631 (84.6%)	
DSI	183 (6.4%)	70 (7.6%)	113 (5.9%)	
No paralytics	225 (7.9%)	73 (7.9%)	152 (7.9%)	
Other method[d]	47 (1.7%)	18 (2%)	29 (1.5%)	
Unknown/Not recorded	2 (0.1%)	0 (0%)	2 (0.1%)	
First attempt device, n (%)				0.46

Table 1 (continued)

	All patients (N = 2846)	Major Adverse event (N = 919)	No major events (N = 1927)	*p*-value
DL—Curved	2294 (80.6%)	733 (79.8%)	1561 (81.0%)	
VL—Standard	444 (15.6%)	154 (16.8%)	290 (15.0%)	
VL—Hyperangulated	73 (2.6%)	25 (2.7%)	48 (2.5%)	
Other device[e]	29 (1%)	6 (0.7%)	23 (1.2%)	
Unknown	6 (0.2%)	1 (0.1%)	5 (0.3%)	
Auxiliary intubation device, n (%)				0.14
Stylet	1466 (51.5%)	450 (49.0%)	1016 (52.7%)	
Bougie	923 (32.4%)	316 (34.4%)	607 (31.5%)	
None	443 (15.6%)	151 (16.4%)	292 (15.2%)	
Other	8 (0.3%)	2 (0.2%)	6 (0.3%)	
Unknown/Not recorded	6 (0.2%)	0 (0%)	6 (0.3%)	
Capnography for intubation confirmation, n (%)	637 (22.4%)	196 (21.3%)	441 (22.9%)	0.51
Cormack-Lehane classification, n (%)				0.003
1	1281 (45%)	380 (41.3%)	901 (46.8%)	
2a	830 (29.2%)	267 (29.1%)	563 (29.2%)	
2b	443 (15.6%)	160 (17.4%)	283 (14.7%)	
3	162 (5.7%)	62 (6.7%)	100 (5.2%)	
4	17 (0.6%)	11 (1.2%)	6 (0.3%)	
Not available	113 (4.0%)	39 (4.2%)	74 (3.8%)	
Apneic oxygenation performed, n (%)				0.009
No	2025 (71.2%)	678 (73.8%)	1347 (69.9%)	
Yes	628 (22.1%)	197 (21.4%)	431 (22.4%)	
Unknown	193 (6.8%)	44 (4.8%)	149 (7.7%)	
Induction analgesia, n (%)				0.014
Fentanyl	630 (22.1%)	172 (18.7%)	458 (23.8%)	
Lidocaine	42 (1.5%)	19 (2.1%)	23 (1.2%)	
Other	99 (3.5%)	31 (3.4%)	68 (3.5%)	
None	2074 (72.9%)	697 (75.8%)	1377 (71.5%)	
Unknown	1 (0%)	0 (0%)	1 (0.1%)	
Induction hypnotic, n (%)				< 0.0001
Etomidate	1655 (58.2%)	499 (54.3%)	1156 (60.0%)	
Ketamine	751 (26.4%)	274 (29.8%)	477 (24.8%)	
Midazolam	145 (5.1%)	32 (3.5%)	113 (5.9%)	
Propofol	89 (3.1%)	29 (3.2%)	60 (3.1%)	
Other[f]	16 (0.6%)	7 (0.8%)	9 (0.5%)	
None	91 (3.2%)	44 (4.8%)	47 (2.4%)	
Unknown	99 (3.5%)	34 (3.7%)	65 (3.4%)	
Induction neuromuscular blocker, n (%)				0.11
Succinylcholine	1589 (55.8%)	494 (53.8%)	1095 (56.8%)	
Rocuronium	1021 (35.9%)	353 (38.4%)	668 (34.7%)	
None	219 (7.7%)	70 (7.6%)	149 (7.7%)	
Other[g]	14 (0.5%)	1 (0.1%)	13 (0.7%)	
Unknown	3 (0.1%)	1 (0.1%)	2 (0.1%)	
First operator specialty, n (%)				0.013
Internal Medicine	1125 (39.5%)	407 (44.3%)	718 (37.3%)	
Emergency Medicine	1097 (38.5%)	323 (35.1%)	774 (40.2%)	
Surgery	156 (5.5%)	47 (5.1%)	109 (5.7%)	
Medical student	102 (3.6%)	22 (2.4%)	80 (4.2%)	
ICU	42 (1.5%)	13 (1.4%)	29 (1.5%)	

Table 1 (continued)

	All patients (N = 2846)	Major Adverse event (N = 919)	No major events (N = 1927)	*p*-value
Anesthesiology	3 (0.1%)	1 (0.1%)	2 (0.1%)	
Other specialty[h]	177 (6.2%)	60 (6.5%)	117 (6.1%)	
Unknown/Not recorded	144 (5.1%)	46 (5.0%)	98 (5.1%)	
First operator training stage, n (%)				< 0.0001
Resident, 1 st year	1351 (47.5%)	430 (46.8%)	921 (47.8%)	
Resident, 2nd year	719 (25.3%)	211 (23.0%)	508 (26.4%)	
Resident, 3rd year	112 (3.9%)	45 (4.9%)	67 (3.5%)	
Resident, 4 th year	2 (0.1%)	1 (0.1%)	1 (0.1%)	
Attending physician	409 (14.4%)	131 (14.3%)	278 (14.4%)	
Medical student	120 (4.2%)	29 (3.2%)	91 (4.7%)	
Other operator[i]	11 (0.4%)	3 (0.3%)	8 (0.4%)	
Unknown/Not recorded	122 (4.3%)	69 (7.5%)	53 (2.8%)	
First-attempt intubation success, n (%)	2116 (74.3%)	609 (66.3%)	1507 (78.2%)	< 0.0001
Difficult intubation, n (%)	198 (7%)	110 (12%)	88 (4.6%)	< 0.0001

IQR: Interquartile range; SD: Standard deviations; RSI: Rapid sequence intubation; DSI: Delayed sequence intubation; BMI: Body mass index: calculated as weight in kilograms divided by height in meters squared; ICU: Intensive care unit; DL: Direct laryngoscopy; VL: Video laryngoscopy; TI: Tracheal intubation; SOFA: Sequential organ failure assessment

*SOFA scores were calculated with last values before intubation, the missing ratio PaO_2/FiO_2 score was adjusted as follows: 0 for $SpO_2 > 98\%$, 1 for SpO_2 92–98%, and 2 for $SpO_2 < 92\%$. Scores of 3 and 4 were not applicable as no patients were on mechanical ventilation

**Time between indication and intubation refers to the estimated interval between the clinical decision to intubate and the first laryngoscopy attempt

a: Administration of a fluid bolus > 15 mL/kg to maintain target blood pressure

b: New requirement for or at least 25% increase in the dose of vasopressor

c: Subjective, global clinical assessment made by the operator before the intubation

d: Alternative methods of intubation, such as awake intubation and nasal intubation

e: Other devices such as fiberoptic intubation, Airway Scope, Airtraq

f: Other possible agents are thiopental and dexmedetomidine

g: Atracurium, cisatracurium, pancuronium and vecuronium are other options

h: Included are all other medical specialties that do not match the above categories, such as neurologists, psychiatrists, and others

i: Included career medical officers, senior medical officers and paramedics

and intubation-related characteristics. These associations remained consistent across multiple sensitivity analyses. Factors associated with MAEs included both nonmodifiable characteristics and potentially modifiable elements, such as first-attempt success, pre-intubation hemodynamic status, and pre-intubation peripheral oxygen saturation.

In 2021, INTUBE study analyzed 2964 intubations in critically ill patients and observed MAEs in 45.2% of cases, a higher incidence compared to 32.3% in our study. They reported new hemodynamic instability in 42.6% of patients, severe hypoxemia in 9.3%, and cardiac arrest during intubation in 3.1% [4]. In contrast, our cohort experienced less new hemodynamic instability (20.0%), and more severe hypoxemia (12.3%) and cardiac arrest (3.5%). In a different population, with slight differences in the definition of MAE, the PREPARE II trial reported findings that were similar to our observations, with an incidence of cardiovascular collapse at 21.0% [20]. In our cohort, the utilization of propofol as an induction agent (3%) and opioids (18%) prior to intubation was notably lower compared to INTUBE cohort (45% and 51%, respectively) [4]. Propofol, while widely used for its rapid onset and short duration of action, is associated with a higher incidence of hemodynamic instability [21, 22]. In a secondary analysis from INTUBE study, propofol was identified as a modifiable factor linked to increased peri-intubation hemodynamic instability, with an aOR of 1.28 [2]. Furthermore, the practice of using opioids as a pre-treatment during emergency intubation is controversial. North American registry cohorts with 15,776 intubations show that opioids were used in only 2.9% of patients [6]. Despite limitations, Ferguson I et al. raised questions about the risk of hypotension when fentanyl is used as pre-treatment during emergency intubation [23]. Differences in drug preferences likely reflect global variations in clinical practice, as illustrated by the significantly higher proportion of anesthesiologists performing intubations in INTUBE cohort (54%) compared to our study (0.4%) [4]. Although the Brazilian model of outsourcing

Table 2 Frequency of peri-intubation adverse events

	All patients (N = 2846)
Any major adverse event	919 (32.3%)
New hemodynamic instability	569 (20.0%)
Type of hemodynamic instability (*n* = 569)	
Systolic BP ≤ 65 mmHg	340 (59.8%)
Needed new vasopressor	272 (47.8%)
Increased dose of vasopressor	183 (32.2%)
Push dose of vasopressor	32 (5.6%)
Needed fluid therapy ≥ 15 ml/kg	34 (6.0%)
Severe hypoxemia	356 (12.5%)
Cardiac arrest	100 (3.5%)
Cardiac arrest immediate outcome (*n* = 100)	
Death	26 (26.0%)
Return of spontaneous circulation	73 (73.0%)
Unknown	1 (1.0%)
Other adverse events	
Transient hypotension	345 (12.1%)
Esophageal intubation (immediate identification, < 5 min)	81 (2.8%)
Arrhythmia	50 (1.8%)
Aspiration	25 (0.9%)
Tooth trauma	12 (0.4%)
Airway injury	7 (0.2%)
Esophageal intubation (delayed identification, > 5 min)	5 (0.2%)
Pneumomediastinum	2 (0.1%)
Vocal cord avulsion	1 (0.0%)

BP: Blood pressure

anesthesia services differs from that in Europe, in many North American centers, anesthesiologists do not commonly perform intubations outside the operating room either [14]. The generalization of this finding depends on the contextual factors of each country regarding airway management operators and specialties.

In our sample, patients experiencing MAEs had a markedly higher 28-day mortality, with an aHR of 1.43 (95% CI 1.26–1.62). These findings align with those reported by Russoto et al., who also found an association between MAEs and 28-day mortality (aOR 1.44, 95% CI 1.19–1.74) [4]. While recent trials have addressed modifiable factors to improve pre-oxygenation and avoid hypoxemia [12] or enhance first-attempt success [14, 24], factors to prevent cardiovascular collapse have not been extensively investigated or were not effective [20, 25]. In our cohort, patients who received fluid resuscitation or vasopressors prior to intubation were more likely to experience MAEs, suggesting a more severe clinical profile at baseline. Although these findings highlight the importance of hemodynamic optimization before intubation, it is also possible that hemodynamic instability serves as a surrogate marker of illness severity not fully captured by the available covariates. This interpretation is supported by the lower E-values observed for hemodynamic instability compared with other MAEs, indicating greater susceptibility to unmeasured confounding.

Recent consensus guidelines from an international Delphi study highlight structured strategies for managing the physiologically difficult airway, emphasizing pre-intubation assessment, hemodynamic stabilization, optimized pre-oxygenation, and careful induction agent selection to minimize peri-intubation adverse events [8]. We identified several key risk factors for MAEs during intubation, consistent with previous research. De Jong et al. highlighted hypotension, hypoxemia, lack of pre-oxygenation, obesity, and age over 75 years as critical risk factors for cardiac arrest [26]. In our cohort, markers of illness severity, including shock index, the number of organ dysfunctions, and vasopressor use, were strongly associated with MAEs. Therefore, targeted efforts to identify and stabilize patients presenting with shock or respiratory failure before intubation are essential. Early optimization of hemodynamic status and oxygenation may reduce the risk of peri-intubation adverse events. Two ongoing international trials, the FLUVA (NCT05318066) and PREVENTION (NCT05014581) trials, are evaluating if pre-emptive vasopressor use can reduce cardiovascular collapse during intubation in critically ill adults and may help clarify the role of hemodynamic optimization in this context. Furthermore, capnography use was limited in our cohort (25%), similar to INTUBE study[4], and likely reflects restricted access to waveform capnography in many resource-limited settings. In contrast, use of a pre-intubation checklist was associated with a lower risk of MAEs (aOR, 0.75), supporting its value as a simple, high-impact intervention to improve the safety of emergency airway management.

Our findings highlight the protective effect of first-attempt intubation success in reducing MAEs (aOR, 0.52), with each additional intubation attempt significantly increasing the odds of severe hypoxemia (aOR, 2.28). Operator specialty was significantly associated with first-attempt success, emergency medicine residents achieved higher success rates, emphasizing the importance of specialized training in emergency airway management. Although anesthesiologists are considered airway, they performed very few intubations in our cohort (3 first-attempt intubations and 11 attempts overall), limiting meaningful comparisons with other specialties. Despite evidence supporting the use of videolaryngoscopes and bougies to improve first-attempt success [27, 28] these devices were underutilized in our cohort, similar to the INTUBE[4] cohort in which

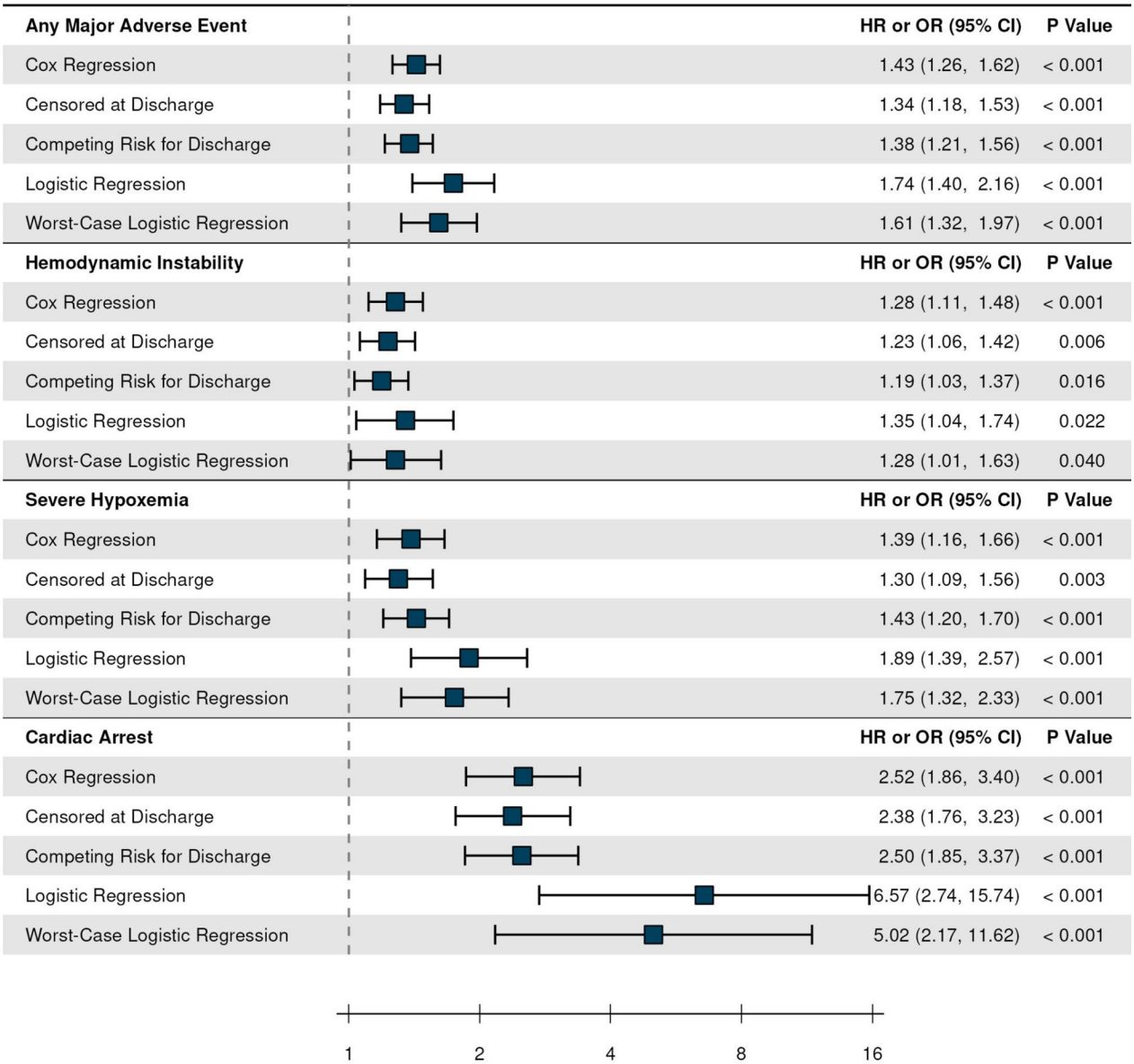

Fig. 2 Association between the occurrence of major adverse events and 28-day mortality. HR: Hazard Ratio; OR: Odds Ratio; CI: Confidence Interval; MAE: Major Adverse Event; Major adverse events peri-intubation were defined as events during or thirty minutes after the intubation process, as listed below: hemodynamic Instability: Systolic Blood Pressure < 65 mmHg, need for starting or increase in vasopressor dose or fluid resuscitation; Severe hypoxemia: Oxygen peripheral saturation less than 80%; Cardiac arrest: Presence of cardiac arrest signs peri-intubation

videolaryngoscopy was used in only 17% of cases. This limited use, along with the high proportion of novice first operators, may have contributed to the lower first-attempt success rate observed in our study (74.3%). The higher incidence of severe hypoxemia (12.5%) compared with Russotto et al[4] may also be explained by this lower first-attempt success rate, as well as the predominant use of bag-valve-mask ventilation for preoxygenation, rather than noninvasive ventilation or high-flow nasal oxygen. Although evidence suggests that stylet use may reduce complications and improve first-attempt success, 15% of patients in our cohort were intubated without any auxiliary devices [29]. Future efforts should focus on improving access to these devices in LMICs.

The choice of induction agent for intubation remains an important area of investigation. In this study, etomidate was associated with fewer MAEs in univariate analysis; however, the association was not significant in the multivariable analysis. The survival benefit of etomidate remains uncertain, and recent evidence, including

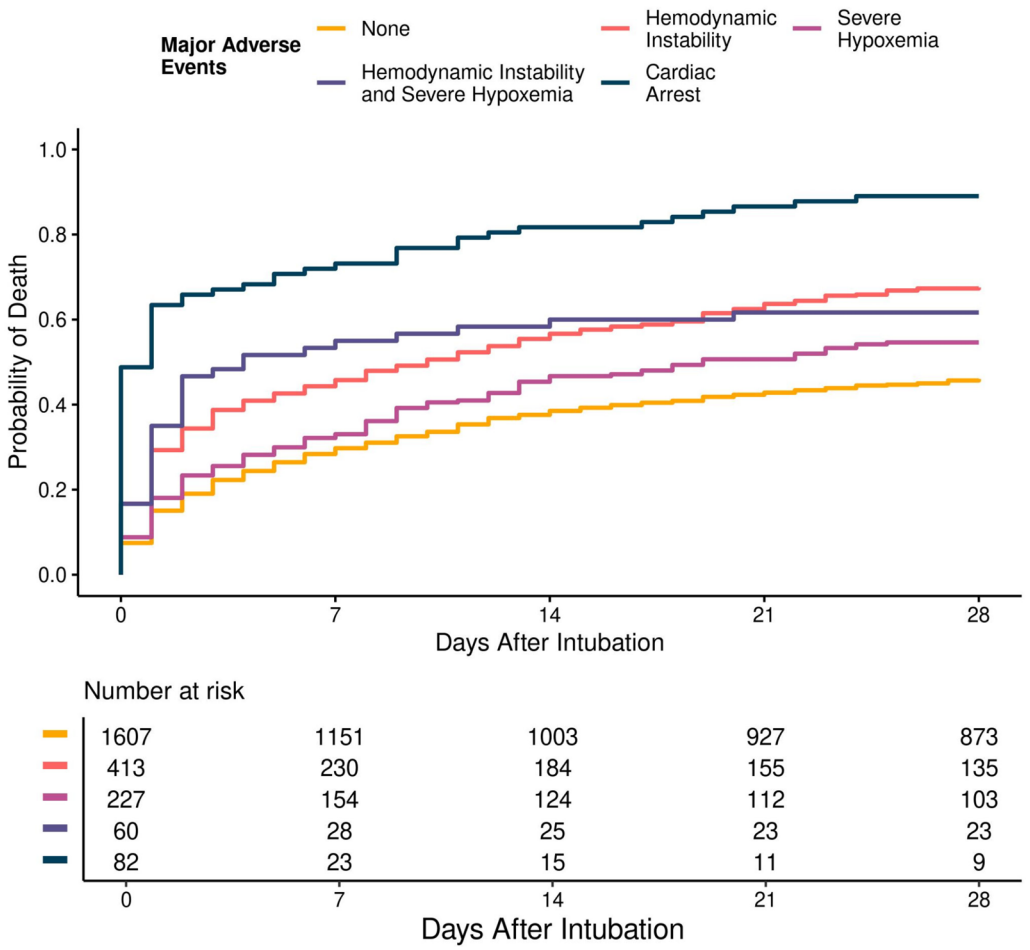

Fig. 3 Mortality rate by days after intubations, stratified by major adverse events. Patients who were discharged were considered alive through the 28-day follow-up period for this analysis

a meta-analysis by Kotani et al., has reported findings favoring ketamine [30–33]. Further research is needed to clarify the comparative effectiveness of induction agents in critically ill patients..

Strengths and limitations

Our study has several strengths. As the first prospective airway cohort established in a low- and middle-income country, this research captures variability in practice beyond what is typically observed in high-income countries. Additionally, we adhered to current best practices in causal inference, carefully selecting confounders and conducting sensitivity analyses to address both modeling assumptions and unmeasured confounding, which enhances the interpretability of our findings.

However, our study has limitations. First, we did not follow up with patients after hospital discharge, which may result in an underestimation of mortality. To address this, we conducted multiple sensitivity analyses to address potential informative censoring, and the effect estimates remained consistent. We did not assess longer-term outcomes either, which would be a gap for future research. Second, despite adjusting for multiple confounders for the association of MAEs with 28-day mortality, the possibility of residual confounding cannot be entirely excluded, particularly in the context of hemodynamic instability, which was more susceptible to unmeasured confounding. Importantly, the other observed associations of multivariable analyses should be interpreted as exploratory to guide future research. Third, although each center had a case manager, not all consecutive intubations were captured in the participating centers. Nonetheless, the incidence of cardiac arrest among non-enrolled patients was comparable to that among enrolled patients, suggesting minimal selection bias. Fourth, while the center enrollment process was broad, most participating centers were academic institutions with emergency residency programs, which may have led to a more selected sample with potentially higher standards of care compared to

Table 3 Association between patient and intubation characteristics with peri-intubation major adverse events

Characteristic	Univariable		Multivariable	
	Odds ratio (95% CI)	***p* value**	**Odds ratio[1] (95% CI)**	***p* value**
Age, per 5 years	1.04 (1.02, 1.07)	0.001	1.05 (1.01, 1.09)	0.019
Sex, male	1.08 (0.92, 1.28)	0.33	–	
BMI, per 5 kg/m2	1.00 (0.98, 1.01)	0.59	–	
Shock index, per 0.1 point	1.13 (1.10, 1.16)	< 0.001	1.10 (1.06, 1.13)	< 0.001
Charlson comorbidity, per 1 point	1.07 (1.03, 1.10)	< 0.001	1.05 (0.99, 1.10)	0.091
SOFA score, per 1 point	1.08 (1.05, 1.11)	< 0.001	1.07 (1.03, 1.11)	< 0.001
Indication for intubation				
Airway protection	-Reference-	–-	-Reference-	–-
Acute respiratory insufficiency	2.41 (2.01, 2.89)	< 0.001	1.65 (1.27, 2.14)	< 0.001
Anticipation of clinical course	1.66 (1.31, 2.11)	< 0.001	1.27 (0.91, 1.75)	0.16
Transport risk	0.26 (0.03, 2.06)	0.20	–	
MACOCHA score, per 1 point	0.95 (0.88, 1.03)	0.20	–	
MACOCHA criteria				
Mouth opening < 3 cm	0.84 (0.51, 1.36)	0.47	–	
Cervical restriction	1.48 (1.14, 1.92)	0.003	1.18 (0.82, 1.68)	0.37
Obstructive apnea	1.32 (0.81, 2.12)	0.26	–	
Glasgow score < 9	0.72 (0.60, 0.87)	< 0.001	1.09 (0.84, 1.43)	0.51
Mallampati grade 3 or 4	0.98 (0.40, 2.40)	0.96	–	
Subjective impression of difficult airway	1.34 (1.12, 1.60)	0.001	1.22 (0.95, 1.57)	0.13
Pre-intubation oxygen saturation, per %	0.94 (0.93, 0.95)	< 0.001	0.94 (0.93, 0.94)	< 0.001
Intubation checklist performed	0.74 (0.60, 0.91)	0.005	0.75 (0.57, 0.98)	0.036
Intubation method				
RSI	-Reference-	–-	Reference	–-
DSI	1.21 (0.88, 1.66)	0.23	–	
Other oral intubation	1.26 (0.86, 1.85)	0.23	–	
Non-oral intubation	1.82 (0.94, 3.54)	0.077	–	
First-attempt—visualization device				
DL—Curved	-Reference-	–	–	–
VL—Standard or Hyperangulated	1.24 (0.99, 1.55)	0.064	–	
Other device	0.62 (0.25, 1.55)	0.31	–	
Auxiliary intubation device				
None	-Reference-	–	Reference	–
Bougie	1.07 (0.82, 1.39)	0.63	1.22 (0.86, 1.73)	0.26
Stylet	0.75 (0.58, 0.96)	0.021	0.95 (0.68, 1.33)	0.76
Other	0.55 (0.11, 2.85)	0.48	0.34 (0.04, 3.37)	0.36
Apneic oxygenation performed	1.00 (0.81, 1.23)	0.98	–	
Cormack-Lehane Class				
1	-Reference-	–	-Reference-	–
2a	1.12 (0.92, 1.35)	0.26	0.94 (0.74, 1.20)	0.62
2b	1.39 (1.10, 1.76)	0.005	1.03 (0.76, 1.41)	0.84
3	1.55 (1.10, 2.19)	0.013	1.00 (0.62, 1.61)	0.98
4	4.61 (1.67, 12.8)	0.003	2.38 (0.61, 1.05)	0.21
Induction analgesia				
None	-Reference-	–	-Reference-	–
Any analgesia	0.80 (0.66, 0.97)	0.024	0.81 (0.62, 1.05)	0.11

Table 3 (continued)

Characteristic	Univariable		Multivariable	
	Odds ratio (95% CI)	*p* value	Odds ratio[1] (95% CI)	*p* value
Induction hypnotic				
Etomidate	-Reference-	–	Reference	–
Ketamine	1.44 (1.18, 1.75)	< 0.001	1.24 (0.94, 1.62)	0.13
Midazolam	0.77 (0.49, 1.19)	0.24	1.49 (0.73, 3.05)	0.27
Propofol	1.13 (0.71, 1.80)	0.60	1.61 (0.85, 3.04)	0.15
Other hypnotic	1.78 (0.64, 4.89)	0.27	1.35 (0.39, 4.75)	0.64
None	2.37 (1.53, 3.65)	< 0.001	1.07 (0.70, 1.61)	0.76
Induction paralytic use				
None	-Reference-	–	Reference	–
Any paralytic	0.75 (0.52, 1.07)	0.11	–	
First operator specialty				
Emergency Medicine	-Reference-	–-	Reference	–-
Internal Medicine	1.14 (0.92, 1.42)	0.23	–	
Surgery	0.86 (0.58, 1.28)	0.46	–	
Medical Student	0.65 (0.39, 1.08)	0.098	–	
ICU	0.96 (0.49, 1.89)	0.91	–	
Other specialty	1.16 (0.81, 1.66)	0.43	–	
First operator age, per year	1.00 (0.98, 1.01)	0.66	–	
First operator experience, per year	1.00 (0.98, 1.02)	0.91	–	
First operator—time on call, per 5 h	1.01 (0.94, 1.09)	0.81	–	

[1] Multivariable model included a LASSO penalty for variable selection. Odds ratios for characteristics excluded from the final model are listed as "–"

Abbreviations: BMI: Body mass index: calculated as weight in kilograms divided by height in meters squared; SOFA: Sequential organ failure assessment; ICU: Intensive care unit; RSI: Rapid sequence intubation; DSI: Delayed sequence intubation; DL: Direct laryngoscopy; VL: Videolaryngoscopy

other centers in Brazil. Fifth, we did not collect specific data on withdrawal of care, which limits our ability to evaluate its impact on 28-day mortality, although there is no strong reason to assume that withdrawal decisions were directly influenced by peri-intubation adverse events, except in cases of peri-intubation cardiac arrest. Furthermore, we did not record the annual rate of intubations performed at each site, limiting our ability to assess how intubation volume or operator experience could have influenced outcomes. Moreover, the inclusion of patients exclusively from emergency departments may be a limitation, as the findings may not fully reflect outcomes among all critically ill patients, particularly regarding the incidence of adverse events and 28-day mortality. However, in our setting, critically ill patients are often intubated in the ED before an ICU bed becomes available. As such, these results provide important insights into the quality of pre-ICU care and highlight opportunities for improvement during this critical period. Lastly, a few centers were rural units without ICU beds, so patients were transferred after stabilization, and we did not have access to 28-day hospital outcomes for these patients.

Conclusions

In conclusion, one in three patients experienced a peri-intubation major adverse event, which may increase 28-day mortality. First-attempt success, pre-intubation hemodynamics, pre-oxygenation, and sedative choices are potentially modifiable factors that may reduce the risk of MAEs. These findings highlight an urgent need for targeted interventions to mitigate peri-intubation adverse events in resource-constrained settings.

Ethics approval and consent to participate

This study was approved by the ethics committees of all participating centres. Due to the observational nature of the study and the use of de-identified data, a waiver of individual patient consent was granted by each institution's ethics committee. Certificate of Presentation for Ethical Consideration at Coordinator Center: CAE-52424821.1.0000.0068.

Consent for publication
Not applicable.

Supplementary Information
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Additional file1

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Author contributions
Ian Ward A. Maia, Gabriela Stanzani, Heraldo P. Souza, and Julio C. G. Alencar conceived and designed the study. All authors participated in data collection. Ian Ward A. Maia and Aidan Mullan performed the data analysis. Ian Ward A. Maia drafted the manuscript, and all authors contributed to the draft. Ian Ward A. Maia, Otavio T. Ranzani, Fernanda Bellolio, Lucas Oliveira J. e Silva, Rafael von Hellmann, Bruno A. M. Pinheiro Besen, and Julio C. G. Alencar critically reviewed and revised the manuscript. All authors approved the final version and are accountable for all aspects of the work.

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Availability of data and materials
The datasets generated for this study are not publicly available, since individual participants did not consent for individual data availability for secondary analyses. Access to the datasets may be provided for secondary analysis upon approval of the steering committee and consent for further data analysis, and further ethical approval may apply. After publication, de-identified individual participant data that underlie the results reported in this article will be made available to researchers who provide a methodologically sound proposal. Proposals should be directed to the corresponding author. To gain access, data requestors will need to sign a data access agreement. Data will be available beginning nine months and ending 36 months following article publication. The study protocol and statistical analysis plan will be available on immediately following publication, with no end date. Aggregate data will be shared in the main manuscript and supplementary materials. Additional related documents, including the informed consent form (in Portuguese with English translation) and the data dictionary, will be available upon reasonable request to the corresponding author. For data access requests or other inquiries, please contact Ian Ward A. Maia at ian.ward@hc.fm.usp.br.

Declarations

Competing interests
The authors declare no competing interests.

Author details
[1]Department of Emergency Medicine, Faculdade de Medicina da Universidade de Sao Paulo, Av. Dr. Enéas Carvalho de Aguiar, 255-Cerqueira César, São Paulo-SP 05403-000, Brazil. [2]Department of Emergency Medicine, Mayo Clinic, Rochester, MN, USA. [3]Medical Sciences Postgraduate Program, Faculdade de Medicina, Universidade de Sao Paulo, Sao Paulo, Brazil. [4]Department of Emergency Medicine, Universidade Federal do Rio Grande do Sul, Hospital de Clinicas de Porto Alegre, Porto Alegre, Rio Grande Do Sul, Brazil. [5]Intensive Care Department, Monash Health, Melbourne, Australia. [6]Department of Emergency Medicine, Hospital Metropolitano Odilon Behrens, Belo Horizonte, Minas Gerais, Brazil. [7]Department of Emergency Medicine, Ribeirao Preto School of Medicine-University of Sao Paulo, Ribeirao Preto, São Paulo, Brazil. [8]Department of Emergency Medicine, Hospital das Clínicas da Faculdade de Medicina de Botucatu, Botucatu, Sao Paulo, Brazil. [9]Department of Emergency Medicine, Hospital Regional de Sao José - Dr. Homero de Miranda Gomes, São José, Santa Catarina, Brazil. [10]Department of Emergency Medicine, Hospital Sao Lucas da Pontificia Universidade Católica Do Rio Grande Do Sul, Porto Alegre, Rio Grande Do Sul, Brazil. [11]Department of Emergency Medicine, Hospital de Pronto Socorro, Porto Alegre, Rio Grande Do Sul, Brazil. [12]Department of Emergency Medicine, Hospital Geral de Fortaleza, Fortaleza, Ceara, Brazil. [13]Department of Emergency Medicine, Hospital Dr. Carlos Alberto Studart Gomes, Fortaleza, Ceara, Brazil. [14]Department of Emergency Medicine, Hospital das Clínicas da Faculdade de Medicina de Marilia, Marilia, Sao Paulo, Brazil. [15]Department of Emergency Medicine, Hospital Augusto de Oliveira Camargo, Indaiatuba, Sao Paulo, Brazil. [16]Department of Emergency Medicine, Hospital Regional Alto Vale, Rio Do Sul, Santa Catarina, Brazil. [17]Department of Emergency Medicine, Hospital Santo Antonio, Sinop, Mato Grosso, Brazil. [18]Department of Emergency Medicine, Hospital Nossa Senhora da Conceição, Porto Alegre, Rio Grande Do Sul, Brazil. [19]Department of Emergency Medicine, Hospital Bruno Born, Lajeado, Rio Grande Do Sul, Brazil. [20]Unidade de Pronto Atendimento de Lajeado, Lajeado, Rio Grande Do Sul, Brazil. [21]Department of Emergency Medicine, Hospital Santa Cruz, Santa Cruz, Rio Grande Do Sul, Brazil. [22]ISGlobal, Barcelona, Spain. [23]Pulmonary Division, Heart Institute, Hospital das Clinicas HCFMUSP, Faculdade de Medicina, Universidade de Sao Paulo, Sao Paulo, Brazil. [24]Faculdade de Medicina de Bauru, Universidade de Sao Paulo, Bauru, Brazil.

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References

1. Mosier JM, Sakles JC, Law JA, Brown CA III, Brindley PG. Tracheal intubation in the critically ill. Where we came from and where we should go. Am J Resp Critic Care Med. 2020;201(7):775–88.
2. Russotto V, Tassistro E, Myatra SN, et al. Peri-intubation cardiovascular collapse in patients who are critically Ill: insights from the INTUBE study. Am J Respir Crit Care Med. 2022;206(4):449–58.
3. Downing J, Yardi I, Ren C, et al. Prevalence of peri-intubation major adverse events among critically ill patients: a systematic review and meta analysis. Am J Emerg Med. 2023;71:200–16.
4. Russotto V, Myatra SN, Laffey JG, et al. Intubation practices and adverse peri-intubation events in critically Ill patients from 29 countries. JAMA. 2021;325(12):1164–72.
5. Heffner AC, Swords DS, Neale MN, Jones AE. Incidence and factors associated with cardiac arrest complicating emergency airway management. Resuscitation. 2013;84(11):1500–4.
6. April MD, Arana A, Reynolds JC, et al. Peri-intubation cardiac arrest in the emergency department: a national emergency airway registry (NEAR) study. Resuscitation. 2021;162:403–11.
7. Myatra SN, Divatia JV, Brewster DJ. The physiologically difficult airway: an emerging concept. Curr Opin Anaesthesiol. 2022;35(2):115–21.
8. Karamchandani K, Nasa P, Jarzebowski M, et al. Society of critical care anesthesiologists (SOCCA) Physiologically difficult airway task force. Tracheal intubation in critically ill adults with a physiologically difficult airway. An international Delphi study. Intensive Care Med. 2024 50(10):1563–1579.
9. Mosier JM, Joshi R, Hypes C, Pacheco G, Valenzuela T, Sakles JC. The physiologically difficult airway. West J Emerg Med. 2015;16(7):1109–17.
10. Kornas RL, Owyang CG, Sakles JC, Foley LJ, Mosier JM. Evaluation and management of the physiologically difficult airway: consensus

recommendations from society for airway management. Anesth Analg. 2021;132(2):395–405.
11. Jaber S, Jung B, Corne P, et al. An intervention to decrease complications related to endotracheal intubation in the intensive care unit: a prospective, multiple-center study. Intensive Care Med. 2010;36(2):248–55.
12. Gibbs KW, Semler MW, Driver BE, et al. Noninvasive ventilation for preoxygenation during emergency intubation. N Engl J Med. 2024;390(23):2165–77.
13. Casey JD, Janz DR, Russell DW, et al. Bag-mask ventilation during tracheal intubation of critically Ill adults. N Engl J Med. 2019;380(9):811–21.
14. Prekker ME, Driver BE, Trent SA, et al. Video versus direct laryngoscopy for tracheal intubation of critically Ill adults. N Engl J Med. 2023;389(5):418–29.
15. von Elm E, Altman DG, Egger M, et al. The Strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. J Clin Epidemiol. 2008;61(4):344–9.
16. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)–a metadata-driven methodology and workflow process for providing translational research informatics support. J Biomed Inform. 2009;42(2):377–81.
17. Harris PA, Taylor R, Minor BL, et al. The REDCap consortium: Building an international community of software platform partners. J Biomed Inform. 2019;95:103208.
18. Lederer DJ, Bell SC, Branson RD, Chalmers JD, Marshall R, Maslove DM, Ost DE, Punjabi NM, Schatz M, Smyth AR, Stewart PW. Control of confounding and reporting of results in causal inference studies. Guidance for authors from editors of respiratory, sleep, and critical care journals. Ann Am Thoracic Soc. 2019;16(1):22–8.
19. VanderWeele TJ, Ding P. Sensitivity analysis in observational research: introducing the e-value. Ann Intern Med. 2017;167(4):268–74.
20. Russell DW, Casey JD, Gibbs KW, et al. Effect of fluid bolus administration on cardiovascular collapse among critically Ill patients undergoing tracheal intubation: a randomized clinical trial. JAMA. 2022;328(3):270–9.
21. de Wit F, van Vliet AL, de Wilde RB, et al. The effect of propofol on haemodynamics: cardiac output, venous return, mean systemic filling pressure, and vascular resistances. Br J Anaesth. 2016;116(6):784–9.
22. Dietrich SK, Mixon MA, Rogoszewski RJ, et al. Hemodynamic effects of propofol for induction of rapid sequence intubation in traumatically injured patients. Am Surg. 2018;84(9):1504–8.
23. Ferguson I, Buttfield A, Burns B, et al. Fentanyl versus placebo with ketamine and rocuronium for patients undergoing rapid sequence intubation in the emergency department: The FAKT study-A randomized clinical trial. Acad Emerg Med. 2022;29(6):719–28.
24. Driver BE, Prekker ME, Klein LR, et al. Effect of use of a bougie vs endotracheal tube and stylet on first-attempt intubation success among patients with difficult airways undergoing emergency intubation: a randomized clinical trial. JAMA. 2018;319(21):2179–89.
25. Janz DR, Casey JD, Semler MW, et al. Effect of a fluid bolus on cardiovascular collapse among critically ill adults undergoing tracheal intubation (PrePARE): a randomised controlled trial. Lancet Respir Med. 2019;7(12):1039–47.
26. De Jong A, Rolle A, Molinari N, et al. Cardiac arrest and mortality related to intubation procedure in critically Ill adult patients: a multicenter cohort study. Crit Care Med. 2018;46(4):532–9.
27. Hansel J, Rogers AM, Lewis SR, Cook TM, Smith AF. Videolaryngoscopy versus direct laryngoscopy for adults undergoing tracheal intubation. Cochrane Database Syst Rev. 2022;4(4):CD011136.
28. von Hellmann R, Fuhr N, Maia IW, Gerberi D, Pedrollo D, Bellolio F, e Silva LO. Effect of Bougie use on first-attempt success in tracheal intubations: a systematic review and meta-analysis. Ann Emergen Med. 2024;83(2):132–44.
29. Jaber S, Rollé A, Godet T, et al. Effect of the use of an endotracheal tube and stylet versus an endotracheal tube alone on first-attempt intubation success: a multicentre, randomised clinical trial in 999 patients. Intensive Care Med. 2021;47(6):653–64.
30. April MD, Arana A, Schauer SG, et al. Ketamine versus etomidate and peri-intubation hypotension: a national emergency airway registry study. Acad Emerg Med. 2020;27(11):1106–15.
31. Kotani Y, Piersanti G, Maiucci G, et al. Etomidate as an induction agent for endotracheal intubation in critically ill patients: a meta-analysis of randomized trials. J Crit Care. 2023;77:154317.
32. Koroki T, Kotani Y, Yaguchi T, et al. Ketamine versus etomidate as an induction agent for tracheal intubation in critically ill adults: a Bayesian meta-analysis. Crit Care. 2024;28(1):48.
33. Matchett G, Gasanova I, Riccio CA, et al. Etomidate versus ketamine for emergency endotracheal intubation: a randomized clinical trial. Intensive Care Med. 2022;48(1):78–91.

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