

# The EXPOS Score for Predicting First-Pass Failure During Video Laryngoscopic Intubation in Critically Ill Adults: Development and External Validation

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## Research Article

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# Abstract

## Background

First-pass intubation failure in critically ill adults is associated with severe peri-intubation complications. Although video laryngoscopy is increasingly used for emergency airway management, no bedside score has been specifically developed to estimate the risk of first-pass failure when video laryngoscopy is planned.

## Methods

We performed a secondary prognostic modeling study using pooled individual patient data from three randomized clinical trials. The derivation cohort comprised patients from PREOXI and DEVICE; the external validation cohort comprised patients from MACMAN. Adults undergoing emergency tracheal intubation with video laryngoscopy were included. The primary outcome was first-pass failure, defined as inability to place an endotracheal tube in the trachea after a single insertion of the video laryngoscope blade. Thirteen preprocedural predictors were prespecified. Logistic regression was used to derive a simplified point-based score, with internal validation by 500 bootstrap replications and external evaluation of discrimination and calibration.

## Results

The derivation cohort included 1,651 patients, of whom 250 (15.1%) had first-pass failure. Six variables were retained: body mass index, absence of chronic pulmonary disease, limited mouth opening, short thyromental distance, secretions or upper-airway edema, and operator experience. The EXPOS Score ranged from 0 to 12 points and showed acceptable discrimination and calibration in the derivation cohort (area under the curve [AUC], 0.70; 95% CI, 0.67–0.74). External validation in 183 patients from MACMAN showed similar performance (AUC, 0.72; 95% CI, 0.64–0.79).

## Conclusions

Among critically ill adults undergoing video laryngoscopic intubation, the EXPOS Score identified patients at increased risk of first-pass failure using 6 simple preprocedural variables. The score may support bedside airway risk stratification, although prospective evaluation is needed to determine whether score-guided preparation improves outcomes.

## Trial registration:

Not applicable to this secondary prognostic modeling analysis. The parent trials were registered at ClinicalTrials.gov: NCT05267652 (PREOXI), NCT05239195 (DEVICE), and NCT02413723 (MACMAN).

## Background

Tracheal intubation is a fundamental procedure in intensive care and emergency airway management, used to secure the airway and facilitate mechanical ventilation in critically ill adults. Even when performed by experienced clinicians, intubation can be technically difficult and may precipitate severe hypoxemia, cardiovascular collapse, airway trauma, or cardiac arrest [1–3].

Because repeated attempts are consistently associated with more peri-intubation complications and worse clinical outcomes [7–9], first-pass success has become a central endpoint in contemporary airway trials [8, 10, 11].

In intensive care, difficult intubation has been reported in approximately 5% to 20% of procedures, depending on the population studied and the definition applied [1, 12]. Critically ill patients are particularly vulnerable to failure on the first attempt because physiologic reserve is often limited and airway conditions may be degraded by edema, secretions, blood, or altered anatomy. Anticipating risk before induction may help clinicians match operator expertise, equipment, and rescue planning to the patient.

In the operating room, several bedside assessments and composite scores have been developed to predict difficult intubation [13–15]. In emergency and intensive care settings, the MACOCHA score was specifically developed for critically ill adults [16], while other tools have mainly been derived for prehospital intubation [17–19]. These instruments predated widespread adoption of video laryngoscopy and may not fully reflect the determinants of first-pass failure during an intended video laryngoscopic approach.

Video laryngoscopy can improve glottic visualization and, in some settings, first-pass success in critically ill adults [11]. However, better visualization does not eliminate difficulties with blade insertion, secretion management, or tracheal tube delivery, and no dedicated score is available to estimate first-pass failure when video laryngoscopy is planned. We therefore pooled individual patient data from three randomized clinical trials to develop and externally validate a simple bedside score for predicting first-pass failure among critically ill adults undergoing video laryngoscopic intubation: the EXPOS Score.

## Methods

### Study design and data sources

Model development and external validation study was reported in accordance with the TRIPOD + AI statement [20]. The derivation cohort was assembled from individual patient data from two randomized clinical trials conducted in emergency departments and intensive care units in the United States: the

Pragmatic Trial Examining Oxygenation Prior to Intubation (PREOXI) trial [22] and the Direct Versus Video Laryngoscope (DEVICE) trial [11]. PREOXI enrolled patients between March 2022 and October 2023 across 24 participating units, and DEVICE enrolled patients between March and November 2022 across 17 participating units.

In both trials, eligible participants were adults aged 18 years or older who required emergency tracheal intubation with a laryngoscope. Intubation was performed according to local best practice, including preoxygenation for at least 3 minutes and induction with a hypnotic agent followed by a rapid-onset neuromuscular blocking agent. Use of a bougie or stylet was left to clinician discretion. Patients were excluded if they were pregnant, incarcerated, or if there was insufficient time for enrollment and randomization. Full eligibility criteria are available in the parent trial publications.

For the present analysis, we included only patients whose first intubation attempt used video laryngoscopy and excluded patients intubated with direct laryngoscopy or other devices. Each parent trial was approved by the relevant ethics committees, and informed consent was obtained or waived according to the original protocols. Pooling of individual patient data for secondary analyses, including the present study, was approved by the Institutional Review Board of the French Intensive Care Society (IRB No. 00014135; approval No. 25–041).

## Outcome measures

The primary outcome was first-pass intubation failure, defined as inability to place an endotracheal tube in the trachea after a single insertion of the video laryngoscope blade into the mouth.

Secondary outcomes included total time to successful intubation, severe hypoxemia ( $\text{SpO}_2 < 80\%$ ), minimum systolic arterial pressure during the procedure, Cormack-Lehane glottic view grade, cardiac arrest during or immediately after the procedure, intensive care unit mortality, and in-hospital mortality.

## Candidate predictors and model development

Based on prior literature, expert opinion, clinical relevance, and availability across the derivation and validation cohorts, we prespecified 13 candidate predictors available before laryngoscopy: age; reason for intubation (acute respiratory failure, altered mental status, shock, or emergency procedure); body mass index ( $< 18.5 \text{ kg/m}^2$ ,  $18.5$  to  $< 25 \text{ kg/m}^2$ , or  $\geq 25 \text{ kg/m}^2$ ); Glasgow Coma Scale score;  $\text{SpO}_2/\text{FiO}_2$  ratio ( $\leq 155$ ,  $> 155$  to  $235$ ,  $> 235$  to  $315$ , or  $> 315$ ); vasopressor use at induction; preexisting pulmonary disease; obstructive sleep apnea; limited mouth opening; reduced thyromental distance; reduced neck mobility or a cervical collar; secretions or upper-airway edema; and operator experience ( $\leq 10$ ,  $> 10$  to  $50$ , or  $> 50$  previous intubations).

We used logistic regression to evaluate the association between each candidate predictor and first-pass failure. Univariable analyses were followed by multivariable modeling using a stepwise selection

procedure to balance model fit and parsimony, with a two-sided significance threshold of  $P < 0.05$  [21, 23]. Effect estimates are reported as odds ratios with 95% confidence intervals. No imputation was performed.

## Score derivation and internal validation

A clinical risk score was derived from the final multivariable model using coefficient-based scaling. Among predictors retained in the final model, the smallest absolute regression coefficient was used as the reference value. For each remaining predictor, the ratio of its coefficient to the reference coefficient was calculated and rounded to the nearest integer to assign points. The total EXPOS Score was the sum of points for all predictors present.

Internal validation was performed using 500 bootstrap replications to estimate optimism in model performance. We report the optimism-corrected C statistic together with calibration and overall performance measures. For clinical interpretability, we additionally defined post hoc exploratory risk strata in the derivation cohort (0–3, 4–5, 6–7, and  $\geq 8$  points) based on observed event rates; these strata were descriptive only and were not externally validated.

## External validation

External validation used individual patient data from the MACMAN randomized clinical trial [10, 24, 25], conducted in seven intensive care units in France in 2015 and comparing video with direct laryngoscopy in critically ill adults requiring emergency intubation. Adults aged 18 years or older were eligible. MACMAN excluded pregnant or breastfeeding women, patients under guardianship, and patients for whom there was insufficient time for inclusion.

Point assignments from the derivation model were applied unchanged in the external validation cohort. Discrimination was quantified using the area under the receiver operating characteristic curve. Calibration and overall performance were assessed using the calibration slope, Hosmer-Lemeshow goodness-of-fit test, and Brier score.

## Statistical analysis

Patients with missing primary outcome data were excluded. Statistical analyses were performed with SAS, version 9.4 (SAS Institute Inc., Cary, NC, USA).

## Use of AI-assisted tools

During manuscript preparation, ChatGPT (OpenAI) was used to assist with English-language editing and manuscript formatting. The authors remain responsible for all scientific content and final wording.

## Results

### Derivation cohort

The derivation cohort included 1,651 patients (median [IQR] age, 59 [43–70] years; 1,035 [62.7%] men). The most common indications for intubation were altered mental status (524 [31.7%]), acute respiratory failure (505 [30.6%]), and shock (462 [28.0%]). At the time of intubation, 834 patients (56.7% of those with available data) had a SpO<sub>2</sub>/FiO<sub>2</sub> ratio < 315, and 389 (23.6%) were receiving vasopressor support before induction medications. The median [IQR] Glasgow Coma Scale score was 11 [7–14]. Most intubations were performed using a standard-geometry blade (75.9%) with a bougie or stylet (96.7%). The most used device was the Storz C-MAC (47.1%), and trained operators, defined by more than 50 previous intubations, performed 44.2% of procedures. Severe hypoxemia occurred in 10.4% of intubations, arterial hypotension in 17.4%, and cardiac arrest in 2.1% (Table 1).

Table 1  
Overview of the derivation and external validation cohorts

| Characteristic                                                                                                                                  | Derivation cohort: DEVICE & PREOXI (N = 1,651) | Validation cohort: MACMAN (N = 183) |
|-------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------|-------------------------------------|
| Age, years                                                                                                                                      |                                                |                                     |
| Mean (SD)                                                                                                                                       | 56.2 (17.66)                                   | 62.7 (15.3)                         |
| Median (IQR)                                                                                                                                    | 59.0 (43.0–70.0)                               | 64.0 (55.0–75.0)                    |
| Indication for intubation, n (%)                                                                                                                |                                                |                                     |
| Acute respiratory failure                                                                                                                       | 505 (30.6)                                     | 69 (37.7)                           |
| Altered mental status                                                                                                                           | 524 (31.7)                                     | 42 (23.0)                           |
| Emergency procedure                                                                                                                             | 160 (9.7)                                      | 21 (11.5)                           |
| Shock                                                                                                                                           | 462 (28.0)                                     | 51 (27.9)                           |
| Body mass index, kg/m <sup>2</sup>                                                                                                              |                                                |                                     |
| No. with data                                                                                                                                   | 1,623                                          | 175                                 |
| Mean (SD)                                                                                                                                       | 28.4 (8.2)                                     | 26.3 (6.7)                          |
| Median (IQR)                                                                                                                                    | 26.9 (22.9–32.4)                               | 25.4 (21.9–29.4)                    |
| Glasgow Coma Scale score                                                                                                                        |                                                |                                     |
| No. with data                                                                                                                                   | 1,645                                          | 183                                 |
| Mean (SD)                                                                                                                                       | 10.4 (4.2)                                     | 12.0 (3.7)                          |
| Median (IQR)                                                                                                                                    | 11 (7–14)                                      | 14 (10–15)                          |
| SpO <sub>2</sub> /FiO <sub>2</sub> ratio, n (%)                                                                                                 |                                                |                                     |
| ≤ 155                                                                                                                                           | 465 (31.6)                                     | 25 (13.7)                           |
| 156–235                                                                                                                                         | 170 (11.5)                                     | 43 (23.5)                           |
| 236–315                                                                                                                                         | 199 (13.5)                                     | 54 (29.5)                           |
| > 315                                                                                                                                           | 638 (43.3)                                     | 61 (33.3)                           |
| Vasopressor use at enrollment, n (%)                                                                                                            | 389 (23.6)                                     | 52 (28.4)                           |
| Pulmonary disease, n (%)                                                                                                                        | 478 (29.0)                                     | 47 (25.7)                           |
| Obstructive sleep apnea, n (%)                                                                                                                  | 100 (6.1)                                      | 11 (6.1)                            |
| Abbreviations: IQR, interquartile range; SBP, systolic blood pressure; SD, standard deviation; SpO <sub>2</sub> , peripheral oxygen saturation. |                                                |                                     |

| Characteristic                                                                                                                                  | Derivation cohort: DEVICE & PREOXI (N = 1,651) | Validation cohort: MACMAN (N = 183) |
|-------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------|-------------------------------------|
| Limited mouth opening, n (%)                                                                                                                    | 170 (10.3)                                     | 27 (15.0)                           |
| Short thyromental distance, n (%)                                                                                                               | 212 (12.8)                                     | 19 (10.5)                           |
| Limited neck mobility or cervical collar, n (%)                                                                                                 | 165 (10.0)                                     | 12 (6.6)                            |
| Secretions / upper-airway edema, n (%)                                                                                                          | 262 (15.9)                                     | 58 (31.7)                           |
| Operator experience, n (%)                                                                                                                      |                                                |                                     |
| ≤ 10 prior intubations                                                                                                                          | 195 (11.8)                                     | 39 (21.4)                           |
| 11–50 prior intubations                                                                                                                         | 724 (43.9)                                     | 75 (41.2)                           |
| > 50 prior intubations                                                                                                                          | 729 (44.2)                                     | 68 (37.4)                           |
| First-pass failure, n (%)                                                                                                                       | 250 (15.1)                                     | 58 (31.7)                           |
| Severe hypoxemia (SpO <sub>2</sub> <80%), n (%)                                                                                                 | 163 (10.4)                                     | 26 (14.9)                           |
| Hypotension (SBP < 90 mmHg), n (%)                                                                                                              | 268 (17.4)                                     | 30 (16.7)                           |
| Cardiac arrest, n (%)                                                                                                                           | 34 (2.1)                                       | 4 (2.2)                             |
| Abbreviations: IQR, interquartile range; SBP, systolic blood pressure; SD, standard deviation; SpO <sub>2</sub> , peripheral oxygen saturation. |                                                |                                     |

First-pass intubation failure occurred in 250 of 1,651 procedures (15.1%). Compared with first-pass success, first-pass failure was associated with higher rates of severe hypoxemia (25.7% vs 7.6%) and cardiac arrest (3.2% vs 1.9%) (Additional file 1: eTable 1).

## Model development

In univariable analyses, seven of the 13 prespecified predictors were associated with first-pass failure (Table 2). In multivariable modeling, six preprocedural variables remained independently associated with first-pass failure and were retained in the final model: body mass index, absence of chronic pulmonary disease, limited mouth opening, short thyromental distance, secretions or upper-airway edema, and operator experience. The final multivariable model had an AUC of 0.70 (95% CI, 0.67–0.74), a calibration slope of 1.00 (95% CI, 0.81–1.19), and a Brier score of 0.12 (Table 3 and Fig. 1).

Table 2  
Main effects in the derivation cohort as odds ratios with 95% confidence intervals

| Variable                                                                                                                                  | Univariable OR (95% CI) | Multivariable OR (95% CI) |
|-------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|---------------------------|
| Age                                                                                                                                       | 0.99 (0.99–1.00)        | NA                        |
| Indication for intubation                                                                                                                 |                         | NA                        |
| Acute respiratory failure (reference)                                                                                                     | —                       |                           |
| Altered mental status                                                                                                                     | 1.02 (0.72–1.44)        |                           |
| Emergency procedure                                                                                                                       | 0.89 (0.53–1.51)        |                           |
| Shock                                                                                                                                     | 1.22 (0.86–1.73)        |                           |
| BMI category                                                                                                                              |                         |                           |
| <18.5 kg/m <sup>2</sup> (reference)                                                                                                       | —                       |                           |
| 18.5–24.9 kg/m <sup>2</sup>                                                                                                               | 2.18 (0.92–5.18)        | 2.36 (0.98–5.71)          |
| ≥25 kg/m <sup>2</sup>                                                                                                                     | 3.35 (1.44–7.76)        | 3.36 (1.42–7.93)          |
| Glasgow Coma Scale                                                                                                                        | 1.02 (0.99–1.05)        | NA                        |
| SpO <sub>2</sub> /FiO <sub>2</sub>                                                                                                        |                         | NA                        |
| ≤155 (reference)                                                                                                                          | —                       |                           |
| 156–235                                                                                                                                   | 1.30 (0.82–2.08)        |                           |
| 236–315                                                                                                                                   | 1.33 (0.86–2.07)        |                           |
| >315                                                                                                                                      | 1.06 (0.76–1.48)        |                           |
| Vasopressor use at inclusion                                                                                                              | 1.17 (0.86–1.59)        | NA                        |
| Absence of chronic pulmonary disease                                                                                                      | 1.35 (0.99–1.84)        | 1.47 (1.06–2.04)          |
| Obstructive sleep apnea                                                                                                                   | 1.34 (0.80–2.25)        | NA                        |
| Limited mouth opening                                                                                                                     | 2.16 (1.49–3.14)        | 1.54 (1.02–2.32)          |
| Short thyromental distance                                                                                                                | 2.59 (1.86–3.63)        | 2.34 (1.61–3.38)          |
| Limited neck mobility or cervical collar                                                                                                  | 1.53 (1.02–2.29)        | NA                        |
| Secretions / upper-airway edema                                                                                                           | 3.07 (2.26–4.19)        | 3.20 (2.32–4.43)          |
| Operator experience                                                                                                                       |                         |                           |
| ≤10 prior intubations                                                                                                                     | 2.25 (1.51–3.35)        | 2.37 (1.56–3.59)          |
| Abbreviations: BMI, body mass index; CI, confidence interval; NA, not applicable/not retained in the multivariable model; OR, odds ratio. |                         |                           |

| Variable                                                                                                                                  | Univariable OR (95% CI) | Multivariable OR (95% CI) |
|-------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|---------------------------|
| 11–50 prior intubations                                                                                                                   | 1.38 (1.02–1.85)        | 1.50 (1.09–2.05)          |
| >50 prior intubations (reference)                                                                                                         | —                       |                           |
| Abbreviations: BMI, body mass index; CI, confidence interval; NA, not applicable/not retained in the multivariable model; OR, odds ratio. |                         |                           |

Table 3  
**EXPOS Score and performance in the derivation cohort** a. Point assignment for the EXPOS Score.

| Factor                                                                                | Assigned points |
|---------------------------------------------------------------------------------------|-----------------|
| Body mass index                                                                       |                 |
| ≤18.5 kg/m <sup>2</sup>                                                               | 0               |
| 18.5–24.9 kg/m <sup>2</sup>                                                           | 2               |
| ≥25 kg/m <sup>2</sup>                                                                 | 3               |
| Limited mouth opening                                                                 | 1               |
| Short thyromental distance                                                            | 2               |
| Secretions / upper-airway edema                                                       | 3               |
| Operator experience                                                                   |                 |
| ≤10 prior intubations                                                                 | 2               |
| 11–50 prior intubations                                                               | 1               |
| >50 prior intubations                                                                 | 0               |
| Absence of pulmonary disease                                                          | 1               |
| b. Performance measures of the final multivariable model and point-based EXPOS Score. |                 |

The simplified EXPOS Score ranged from 0 to 12 points (Table 3) and performed similarly to the full multivariable model. The frequency of first-pass failure across the observed score range is shown in Fig. 2. For clinical interpretability, post hoc exploratory risk strata in the derivation cohort corresponded to observed first-pass failure rates of 5.2% (20/387) for scores 0–3, 11.7% (93/793) for scores 4–5, 25.4% (80/315) for scores 6–7, and 41.6% (52/125) for scores ≥ 8. Diagnostic performance across score thresholds is provided in Additional file 1 (eTable 2).

## External validation

The external validation dataset included 183 patients from the MACMAN trial (median [IQR] age, 64 [55–75] years; 120 [65.6%] men and 63 [34.4%] women). Reasons for intubation were broadly similar to those

in the derivation cohort. Compared with the derivation cohort, the MACMAN cohort had a higher prevalence of secretions or upper-airway edema (31.7% vs 15.9%) and a higher proportion of operators with  $\leq 10$  prior intubations (21.4% vs 11.8%). Only the McGrath MAC video laryngoscope with a standard-geometry blade was used, without a bougie or stylet on the first attempt. First-pass failure occurred in 58 of 183 procedures (31.7%) (Table 1).

In the external validation cohort, the AUC for first-pass failure was 0.72 (95% CI, 0.64–0.79), the calibration slope was 1.03 (95% CI, 0.56–1.51), the Hosmer-Lemeshow P value was 0.08, and the Brier score was 0.20 (Table 4 and Fig. 3).

Table 4  
EXPOS Score performance in the external validation cohort

| Measure                                                                                              | MACMAN validation cohort |
|------------------------------------------------------------------------------------------------------|--------------------------|
| AUC (95% CI)                                                                                         | 0.72 (0.64–0.79)         |
| Calibration slope (95% CI)                                                                           | 1.03 (0.56–1.51)         |
| Hosmer-Lemeshow P value                                                                              | 0.08                     |
| Brier score                                                                                          | 0.20                     |
| Abbreviations: AUC, area under the receiver operating characteristic curve; CI, confidence interval. |                          |

## Discussion

In this pooled analysis of critically ill adults undergoing tracheal intubation with video laryngoscopy, the EXPOS Score, a simple six-variable bedside tool, estimated the risk of first-pass failure with moderate discrimination and acceptable calibration in both derivation and external validation cohorts. These findings suggest that, even in the era of widespread video laryngoscopy, clinically meaningful heterogeneity in the probability of first-pass success remains and can be captured using variables available before laryngoscopy.

In critically ill adults, failure on the first intubation attempt has consistently been associated with increased risk of severe hypoxemia, hemodynamic instability, airway trauma, and cardiac arrest [1, 2]. Because physiologic reserve is often limited in intensive care and emergency settings, even brief procedural difficulty may translate into major adverse events. In our derivation cohort, first-pass failure was associated with higher rates of severe hypoxemia and cardiac arrest, supporting the clinical relevance of identifying higher-risk patients before induction.

One important implication of the present study is that video laryngoscopy, although increasingly adopted as a default intubation strategy, does not eliminate the need for preprocedural airway risk stratification. Randomized trials have shown that video laryngoscopy may improve glottic visualization and, in some settings, first-pass success compared with direct laryngoscopy, but this benefit is neither uniform nor absolute [10, 11, 26]. Better visualization does not necessarily ensure successful tube delivery, especially

when mouth opening is limited, thyromental distance is reduced, or the airway is obscured by secretions or edema. The determinants of first-pass failure during video laryngoscopy therefore extend beyond glottic view alone and include both anatomic and procedural constraints.

The variables retained in the EXPOS Score are clinically coherent. Limited mouth opening and short thyromental distance are longstanding markers of difficult laryngoscopy and intubation in perioperative practice [27]. Their persistence in this model suggests that conventional anatomic predictors remain relevant even when video laryngoscopy is planned. Likewise, secretions or upper-airway edema is particularly important in critically ill patients, in whom airway contamination may require suctioning and can interfere with visualization and tube advancement. Higher body mass index may also identify patients with airway conditions that make manipulation more challenging and with less physiologic tolerance of procedural delay [26].

Operator experience was independently associated with first-pass failure, underscoring that successful video laryngoscopic intubation depends not only on the device but also on technical proficiency. Video laryngoscopy may improve the view of the glottis, but it does not remove the need for coordinated blade positioning, optimization maneuvers, appropriate tube shaping, and advancement under indirect vision. The association between operator experience and first-pass success therefore supports the potential use of the score as a preparation tool: a higher-risk patient may warrant earlier involvement of the most experienced available airway operator. To facilitate bedside interpretation, we also summarized the point-based score into four exploratory risk strata (0–3, 4–5, 6–7, and  $\geq 8$  points), which showed progressively higher observed failure rates in the derivation cohort. Because these categories were derived post hoc and were not separately evaluated in the external cohort, they should be interpreted as descriptive aids rather than validated clinical decision thresholds.

The external validation findings strengthen the potential applicability of the score. Despite important differences between derivation and validation cohorts, including country, practice environment, video laryngoscope type, first-attempt adjunct use, and event rate, discrimination remained similar. The score therefore appears to capture patient- and operator-level determinants of first-pass failure that are not restricted to a single device configuration. Nevertheless, the wide confidence interval around the external calibration slope reflects the limited size of the validation cohort and warrants cautious interpretation.

The EXPOS Score complements rather than replaces existing airway assessment tools. MACOCHA was an important step in identifying ICU patients at risk for difficult intubation [16], but it was developed before contemporary widespread use of video laryngoscopy and was designed to predict difficult intubation rather than first-pass failure. The original MACOCHA study reported strong discrimination, whereas more recent independent evaluations have reported lower performance, including an AUC of 0.659 for difficult intubation in critically ill patients and an AUC of 0.593 for first-pass success in an emergency department cohort [33, 34]. By contrast, EXPOS was developed specifically in patients undergoing video laryngoscopy and targets the clinically salient outcome of first-pass failure. Its most

plausible role is not to dictate device choice, but to support pre-intubation planning, including assignment of expertise, early preparation of rescue devices, and explicit backup strategies.

This study has limitations. First, discrimination was moderate, and the score should inform bedside judgment rather than replace it. Second, the external validation cohort was relatively small, limiting precision around performance estimates. Third, candidate predictors were restricted to variables collected across the parent trials, and some conventional airway examination findings used in elective anesthesia, such as Mallampati classification, were unavailable. This limitation also reflects emergency airway practice: Bair et al. found that a Mallampati assessment could be performed in only 26% of patients requiring emergency intubation [30]. In addition, some variables collected in the parent randomized trials were not defined using uniform quantitative cutoffs across datasets; reduced thyromental distance and limited mouth opening, for example, were recorded clinically rather than according to identical prespecified thresholds. Fourth, the model was derived among adults intubated with video laryngoscopy, predominantly using standard-geometry blades, and should not be extrapolated to direct laryngoscopy, all blade designs, or other airway devices used outside the operating room [31, 32]. Finally, because the derivation dataset originated from randomized trials conducted in relatively protocolized environments, performance may differ in less standardized settings.

Prospective studies are now needed to determine whether score-guided airway preparation can improve first-pass success and reduce peri-intubation complications.

## Conclusions

In critically ill adults undergoing tracheal intubation with video laryngoscopy, the EXPOS Score identified patients at increased risk of first-pass failure and showed similar performances in external validation. If confirmed in larger and more diverse cohorts, the score may help structure airway preparation and support earlier escalation of expertise before induction.

## Declarations

## Ethics approval and consent to participate

The parent randomized trials were approved by their respective ethics committees, and informed consent was obtained or waived according to local regulations and the original trial protocols. Pooling of individual patient data for secondary analyses, including the present study, was approved by the Institutional Review Board of the French Intensive Care Society (IRB No. 00014135; approval No. 25-041).

## Consent for publication

Not applicable.

# Availability of data and materials

The datasets analyzed during the current study are available from the corresponding author on reasonable request, subject to applicable data-use agreements, ethics requirements, and approval by the relevant data custodians.

## Competing interests

JBL reports lecture fees from Masimo outside the submitted work. The other authors declare that they have no competing interests.

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## List of abbreviations

AUC, area under the receiver operating characteristic curve; BMI, body mass index; CI, confidence interval; ED, emergency department; ICU, intensive care unit; IQR, interquartile range; OR, odds ratio; SpO<sub>2</sub>, peripheral oxygen saturation; TRIPOD + AI, Transparent Reporting of a multivariable prediction model for Individual Prognosis Or Diagnosis + Artificial Intelligence.

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## Figures

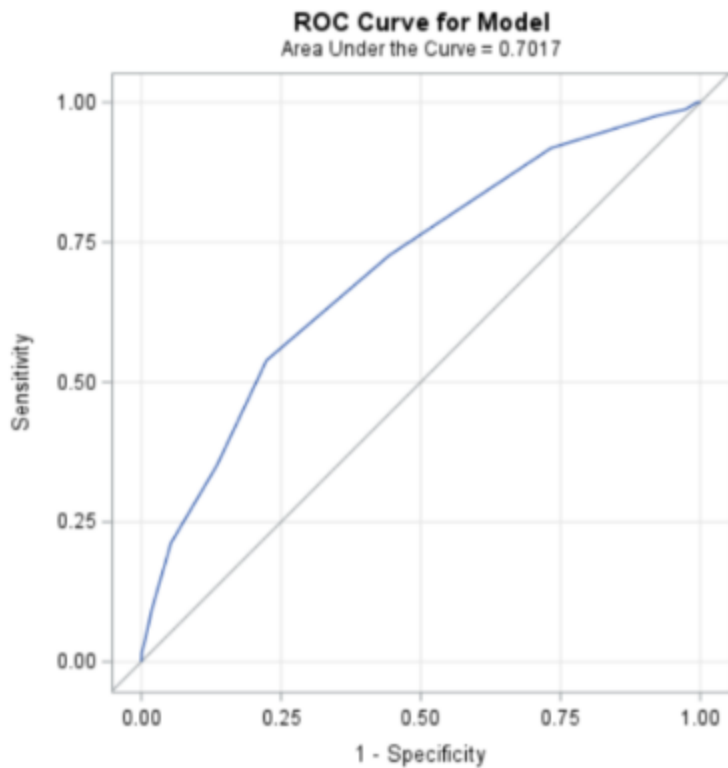


Figure 1

### ROC curve of the final model in the derivation cohort.

Receiver operating characteristic (ROC) curve for prediction of first-pass failure by the final multivariable model. AUC, area under the curve.

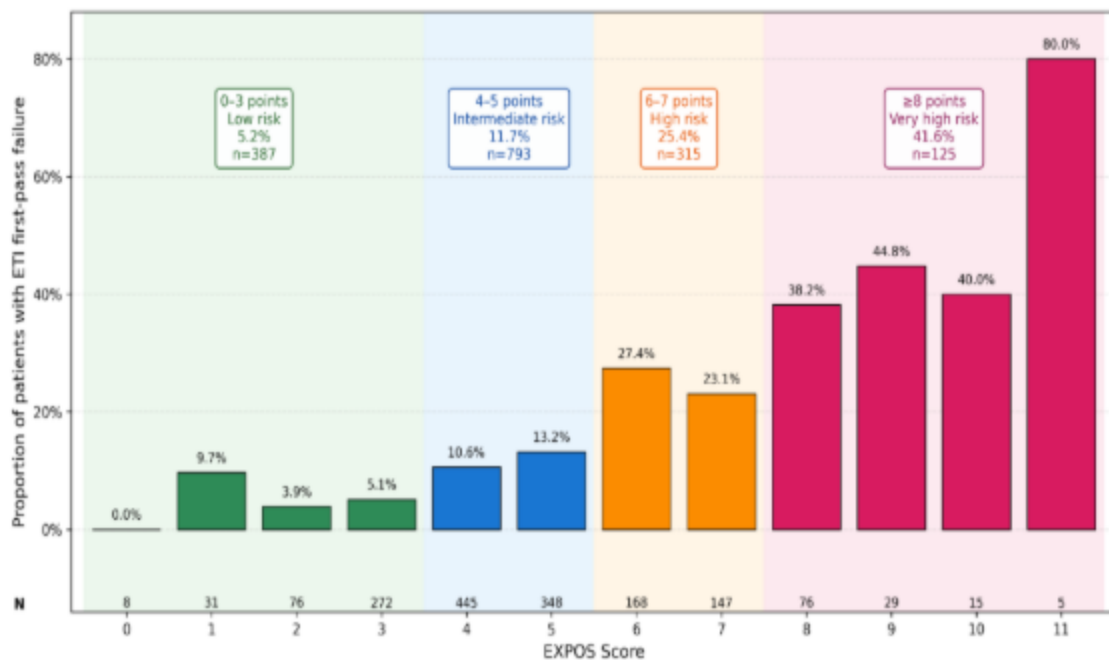
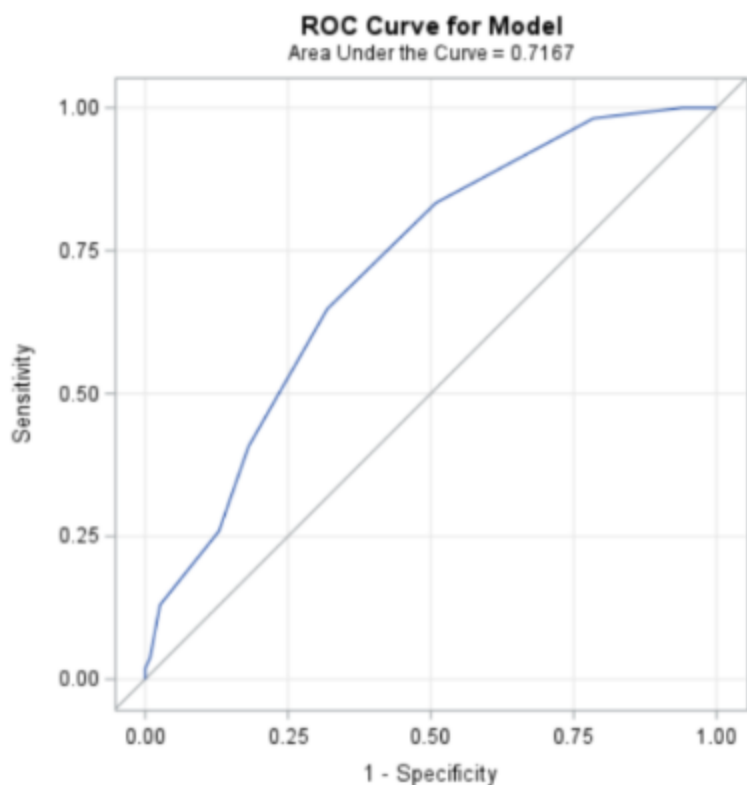


**Figure 2**

### First-pass failure by EXPOS Score and exploratory risk groups in the derivation cohort.

Observed frequency of first-pass intubation failure across EXPOS Score values. Colored bands indicate exploratory derivation-cohort risk strata defined post hoc for clinical interpretability: scores 0–3 (low risk, 5.2%), 4–5 (intermediate risk, 11.7%), 6–7 (high risk, 25.4%), and ≥8 (very high risk, 41.6%). The number of patients contributing to each score category is displayed below the x-axis.



### Figure 3

#### ROC curve of the EXPOS Score in the validation cohort.

Receiver operating characteristic (ROC) curve for prediction of first-pass failure by the point-based EXPOS Score in the MACMAN external validation cohort. AUC, area under the curve.

## Supplementary Files

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