RESEARCH

Colorado Pediatric Airway Score (COPUR) as a Predictor of Intubation Difficulty in Children Aged 1-8 Years

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ABSTRACT

Background: Airway management is critical in pediatric anesthesia, as failure can lead to severe complications, including cardiac arrest. Anticipating and preparing for difficult intubation is essential, particularly in children with unique anatomical and physiological characteristics. The Colorado Pediatric Airway Score (COPUR) is a predictive tool for assessing intubation difficulty in pediatric patients.

Objective: This study evaluates the validity of COPUR in predicting difficult intubation in children.

Methods: A cross-sectional diagnostic study was conducted on 121 pediatric patients (aged 1–8 years) undergoing general anesthesia at Cipto Mangunkusumo Hospital. COPUR assesses jaw structure, mouth opening, prior intubation history, uvula visibility, neck movement, and additional modifying factors (macroglossia, obesity, mucopolysaccharidosis, and protruding teeth). A COPUR score >7 was used to predict difficult intubation, while intubation difficulty was defined by an Intubation Difficulty Score (IDS) >5.

Results: A COPUR score ≥8 predicted difficult intubation in 15.7% of patients, whereas actual difficult intubation occurred in 9.92%. A COPUR threshold of ≥7 provided optimal sensitivity (83.3%) and specificity (61.47%), outperforming the original cutoff of 8 (50% sensitivity, 87% specificity). The score demonstrated good discriminative ability (AUC-ROC: 0.770, 95% CI: 0.685–0.842) and suitable calibration (Hosmer-Lemeshow test, p = 0.584).

Conclusion: The COPUR score is a valid tool for predicting difficult intubation in pediatric patients aged 1–8 years, demonstrating fairly good discrimination and calibration values.

Keywords: colorado pediatric airway score; cross-sectional study; difficult intubation; intubation difficulty scale; pediatric patients

INTRODUCTION

Airway management is a critical component of pediatric anesthesia.[1,2] Failure to secure the airway can result in severe complications, including long-term consequences and even death.[2,3,4] Tracheal intubation is the most reliable method for securing the airway, particularly in pediatric patients.[5,6,7]

The American Society of Anesthesiologists (ASA) defines difficult airway management as a clinical situation in which an experienced anesthesiologist encounters difficulty with face mask ventilation, tracheal intubation, or both.[7] Difficult intubation, defined as failure of direct laryngoscopy-assisted intubation, occurs in approximately 5.8% of cases, with two-thirds being unanticipated.[8,9,10] It can lead to hypoxia, brain injury, and, in extreme cases, death.[11] Although pediatric intubation complications are less frequent than in adults, they pose significant risks due to children's limited physiological reserves.[4]

Pediatric airway management is inherently more challenging due to anatomical and physiological differences. Children have a relatively larger occiput, a higher and more anterior larynx, a proportionally larger tongue, and a more collapsible cervical spine, all of which make laryngoscopy more difficult.[2,9,12] Compared to adults, pediatric patients have a higher oxygen consumption rate but lower oxygen storage capacity. Consequently, they exhibit reduced tolerance to respiratory interruptions, leading to more rapid oxygen desaturation, followed by bradycardia, which subsequently decreases the success rate of subsequent intubation attempts.[1,9,10]

Anticipation and preparation for difficult intubation are crucial to preventing airway management failure, particularly in pediatric patients with distinct anatomical, physiological, and developmental characteristics.[12-16] A thorough pre-anesthetic airway assessment is essential for effective anticipation and preparation. However, pediatric airway evaluation is often less systematically performed than in adults.[10] Predictable airway difficulties include congenital syndromes and acquired anatomical abnormalities, such as temporomandibular joint dysfunction or neck contractures.[12,13] Assessing the pediatric airway can be challenging due to limited patient cooperation, especially in preschool-aged children. The 1–8-year age group represents a transitional phase, where airway anatomy begins to resemble that of adults after the age of eight.[17]

The Colorado Pediatric Airway Score (COPUR) is a structured airway assessment tool that evaluates multiple airway parameters, including chin size, mouth opening, prior intubation history, uvula visibility, and neck mobility, with additional modifying factors.[7] The total score stratifies patients into categories ranging from easy intubation to mildly difficult (requiring cricoid pressure), difficult (necessitating fiberoptic bronchoscopy), and highly difficult (requiring advanced airway management and emergency preparedness).[6,7,12,14] Despite its widespread use, its accuracy in children aged 1–8 years remains unvalidated.[3,7] at Cipto Mangunkusumo Hospital, this age group constitutes 48% of pediatric surgeries, highlighting the need for a validated airway assessment tool to enhance preoperative airway management and improve patient safety.

METHOD

This cross-sectional study was conducted in the Cipto Mangunkusumo Hospital operating room from February to April 2024. The sample size was determined using a diagnostic sensitivity-based formula, accounting for a 10% dropout rate, yielding 121 participants. Ethical approval was obtained from the Faculty of Medicine, Universitas Indonesia Ethics Committee.

Pediatric patients aged 1–8 years with ASA physical status 1–3 undergoing general anesthesia were included upon guardian consent. Exclusion criteria encompassed upper airway pathology (e.g., tumors, maxillofacial fractures), orofacial anomalies (e.g., cleft lip), facial or cervical trauma, restricted mouth opening, congenital syndromes compromising airway patency, critical illness, medical emergencies, and gastric distension necessitating rapid sequence induction.

This study commenced upon approval from the Research Ethics Committee of the Faculty of Medicine, Universitas Indonesia, and Cipto Mangunkusumo Hospital. Informed consent was obtained from guardians one day before surgery, following a detailed explanation of the study protocol. Preoperative assessment was conducted in the operating room reception area, including history-taking and physical examination. Patient data—age, weight, height, and body mass index (BMI)—were recorded, and inclusion/exclusion criteria were evaluated. The COPUR score was assessed based on previous intubation history, sleep-related snoring, congenital syndromes, tongue size, mucopolysaccharidosis, chin size, mouth opening (interdental distance), uvula visibility, and range of motion for neck mobility.

Premedication was as needed, consisting of intravenous ketamine (0.5 mg/kg) and midazolam (0.05 mg/kg). Patients were then transferred to the operating room, where pulse oximetry, non-invasive blood pressure monitoring, and electrocardiography were applied. Preoxygenation was performed with 60% oxygen, followed by inhalational induction using 1–2 MAC sevoflurane. Loss of the eyelash reflex indicated anesthesia onset, followed by positive pressure ventilation and IV access placement if necessary. Anesthesia was maintained with fentanyl (2–3 mcg/kg) and atracurium (0.5 mg/kg). After 2 minutes, anesthesia depth was assessed via jaw thrust. If the jaw was flaccid and there was no motor response or heart rate increase >20% from baseline, anesthesia was deemed sufficient for laryngoscopy; otherwise, inhalational anesthesia was deepened.

Laryngoscopy was performed in the sniffing position, achieved by slight anterior flexion at the atlanto-occipital joint or chin lift. The procedure was conducted by anesthesia trainees who had completed pediatric anesthesia rotations, using an age-appropriate Macintosh laryngoscope. Intubation parameters were recorded, including the number of attempts, operator changes, vocal cord visualization (Cormack-Lehane grade), cricoid pressure application, laryngoscope lifting force, vocal cord position, and alternative intubation techniques. Intubation difficulty was scored using the intubation difficulty scale (IDS). Maintenance anesthesia was then administered for the surgical procedure.

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 25 and presented as narratives, tables, and graphs. Bivariate analysis of COPUR scores and intubation difficulty was conducted using the Chi-Square or Kolmogorov-Smirnov test. Variables with $p < 0.25$ were included in multivariate analysis, which was performed using logistic regression. The accuracy of the COPUR score was evaluated through discrimination (receiver operating characteristic curve) and calibration (Hosmer-Lemeshow test). The population-specific COPUR score cut-off was determined from the area under the curve (AUC).

RESULTS

A total of 121 pediatric patients (Table 1) met the inclusion criteria and were not excluded. No subjects were withdrawn from the study. In the bivariate analysis (Table 2) of demographic scores in relation to intubation difficulty, no statistically significant components were identified. However, a trend was observed where older age (≥3 years) was associated with an increased risk of difficult intubation compared to the 1–2 year age group. Sex appeared to have a protective effect against difficult intubation. The BMI-for-age analysis indicated that undernutrition (>-3 SD to <-2 SD) and obesity increased the risk of difficult intubation.

The risk of difficult intubation was significantly higher in patients with a uvula score of 3 compared to those with a uvula score of 1 [OR 13.77; 95% CI (1.189 – 159.50); p = 0.036]. Further analysis of predictors of intubation difficulty revealed that obesity significantly increased the risk of difficult intubation [OR 7.067; 95% CI (1.054 – 47.391); p = 0.044]. A total COPUR score with a cutoff of ≥7 was also associated with a significantly increased risk of difficult intubation [OR 7.976; 95% CI (1.665 – 38.202); p = 0.009] (Table 3).

The threshold value for the COPUR score in the population was determined by assessing the intersection of the sensitivity and specificity curves and evaluating the Youden Index. The optimal cutoff point, providing the best balance between sensitivity and specificity, was identified between >6 and <7 (Figure 1). The highest Youden Index was 0.448, with a COPUR score cutoff of ≥7, indicating a sensitivity of 83.3% (95% CI: 51.6 – 97.9) and a specificity of 61.47% (95% CI: 51.7 – 70.6). The positive predictive value (PPV) and negative predictive value (NPV) for a COPUR score of ≥7 were 19.24% (95% CI: 14.41 – 25.2) and 97.1% (95% CI: 90.35 – 99.17), respectively. The positive likelihood ratio (LR+) and negative likelihood ratio (LR−) for a COPUR score of ≥7 were 2.16 (95% CI: 1.53 – 3.06) and 0.27 (95% CI: 0.076 – 0.97), respectively (Table 4).

Variables that met the inclusion criteria (p-value < 0.25 in the bivariate analysis) and were included in the multivariate logistic regression analysis were BMI-for-age, previous intubation, obesity, and uvula score. From the final model in the multiple logistic regression analysis (Table 5), the resulting equation is: $y = -3.045 + (1.206 \times \text{uvula }(1)) + (3.045 \times \text{uvula }(2))$.

The Area Under the Curve (AUC) was 0.770 with 95% CI: 0.685–0.842 and p < 0.001 (Figure 2). This indicates that the COPUR score with a cutoff of ≥7, when assessed during intubation, can significantly distinguish between subjects experiencing difficult intubation (IDS >5) and those with easy intubation, with an accuracy of 77.0% (ranging from 68.5% to 84.2%).

The Hosmer-Lemeshow test yielded a p-value of 0.584 (p > 0.05), indicating that the COPUR score with a cutoff of ≥7 demonstrates a good fit for predicting difficult intubation (Figure 3).

Table 1. Baseline characteristics of study subjects

Baseline characteristics	N (%) (n=121)
Age (years)	3 (1-8)
Body weight[a] (kg)	12.6 (6.4-40)
Height[a] (cm)	95 (62-134)
Body mass index[a] (kg/m^2)	14.33 (8.06-28.67)
Sex	
Male	68 (56.2%)
Female	53 (43.8%)
Body mass index-for-age	
Severely underweight (<-3SD)	25 (20.7%)
underweight (-3SD to <-2SD)	14 (11.6%)
Normal (-2SD to +2SD)	70 (57.9%)
Overweight (>+2SD to +3SD)	7 (5.8%)
Obese (>+3SD)	5 (4.1 %)
American Society of Anesthesiologists (ASA) Physical Status Classification	
ASA 1	32 (26.4%)
ASA 2	37 (30.6%)
ASA 3	52 (43.0%)
Type of surgery	
Pediatric surgery	10 (8.3%)
Oral and maxillofacial surgery	19 (15.7%)
Orthopedic surgery	12 (9.9%)
Plastic surgery	15 (12.4%)
Neurosurgery	1 (0.8%)
Thoracic and cardiovascular surgery	20 (16.5%)
Urological surgery	22 (18.2%)
Vascular surgery	1 (0.8%)
Otorhinolaryngology (ENT) surgery	5 (4.1%)
Pediatric	16 (13.2%)

[a]For non-normally distributed data, results are presented as the median (minimum-maximum values)
[b]For normally distributed data, results are presented as the mean (± standard deviation)

Table 2. Bivariate analysis of demographic characteristics and intubation difficulty

Variables	Easy intubation IDS ≤5	Difficult intubation IDS > 5	p-value	OR (95% CI)
Age				
1-2 years old	49 (9.2%) [b]	3 (5.8%)	N/A	Reference
3-5 years old	34 (87.2%)	5 (12.8%)	0.251	2.402 (0.538-10.730)
6-8 years old	26 (86.7%)	4 (13.3%)	0.250	2.513 (0.522-12.086)
Sex				
Male	60 (88.2%) [a]	8 (11.8%)	N/A	Reference
Female	49 (92.5%)	4 (7.5%)	0.445	0.612 (0.174-2.154)
Body mass index-for-age				
Severely underweight (<-3SD)	25 (100.0%) [b]	0 (0.0%)	N/A	N/A
underweight (-3SD to <-2SD)	12 (85.7%)	2 (14.3%)	0.7644	1,292 (0.244 – 6.8496)
Normal (-2SD to +2SD)	62 (88.6%)	8 (11.4%)	N/A	Reference
Overweight (>+2SD to +3SD)	7 (100.0%)	0 (0.0%)	N/A	N/A
Obese (>+3SD)	3 (60.0%)	2 (40.0%)	0.0962	5.167 (0.746 – 35.76)
Cormack-Lehane				
Cormack-Lehane 1-2	109 (90.83%)	11 (9.17%)	N/A	N/A
Cormack-Lehane 3-4	0 (0.0%)	1 (100.0%)	N/A	N/A

a= Fisher Exact test, b= Kolgomorov-Smirnov Z test
IDS: Intubation Difficulty Score; OR: odds ratio; CI: confidence interval

Table 3. Bivariate analysis of COPUR components and intubation difficulty

Variables	Easy intubation IDS ≤5	Difficult intubation IDS > 5	p-value	OR (95% CI)
Chin				
1	95 (91.3%)[a]	9 (8.7%)	N/A	Reference
2	13 (86.7%)	2 (13.3%)	0.5618	1.628 (0.3156 – 8.356)
3	1 (100.0%)	0 (0.0%)	N/A	N/A
4	0 (0.0%)	1 (100.0%)	N/A	N/A
Opening of The Mouth				
1	106 (89.8%)	12 (10.2%)	N/A	N/A
2	3 (100.0%)	0 (0.0%)	N/A	N/A
3	0 (0.0%)	0 (0.0%)	N/A	N/A
4	0 (0.0%)	0 (0.0%)	N/A	N/A
Previous Intubation/Obstructive Sleep Apnea (OSA)				
1	48 (96.0%)[b]	2 (4.0%)	N/A	Reference
2	49 (90.7%)	5 (9.3%)	0.280	2.582 (0.462 – 14.41)
3	12 (70.6%)	5 (29.4%)	0.075*	5.97 (0.835 – 42.695)
4	0 (0.0%)	0 (0.0%)	N/A	N/A
Uvula				
1	63 (95.5%)[b]	3 (4.5%)	N/A	Reference
2	44 (86.3%)	7 (13.7%)	0.244	2.413 (0.547 – 10.640)
3	2 (50.0%)	2 (50.0%)	0.036*	13.771 (1.189 – 159.50)
4	0 (0.0%)	0 (0.0%)	N/A	N/A
Range of Motion				
1	109 (90.9%)	12 (9.9%)	N/A	Reference
2	0 (0.0%)	0 (0.0%)	N/A	N/A
3	0 (0.0%)	0 (0.0%)	N/A	N/A
4	0 (0.0%)	0 (0.0%)	N/A	N/A
Macroglossia				
Yes	4 (100.0%)	0 (0.0%)	N/A	N/A
No	105 (89.7%)	12 (10.3%)	N/A	N/A
Obesity				
Yes	3 (60.0%) [a]	2 (40.0%)	0,044*	7.067 (1.054 – 47.391)
No	106 (91.4%)	10 (8.6%)	N/A	Reference
COPUR score				
<7	67(97.1%) [a]	2 (2.9%)	N/A	Reference
≥7	42 (80.7%)	10 (19.3%)	0.009*	7.976 (1.665 – 38.202)

a= Fisher Exact test, b= Kolgomorov-Smirnov Z test

IDS: Intubation Difficulty Score; OR: odds ratio; CI: confidence interval; COPUR: Colorado Pediatric Airway Score

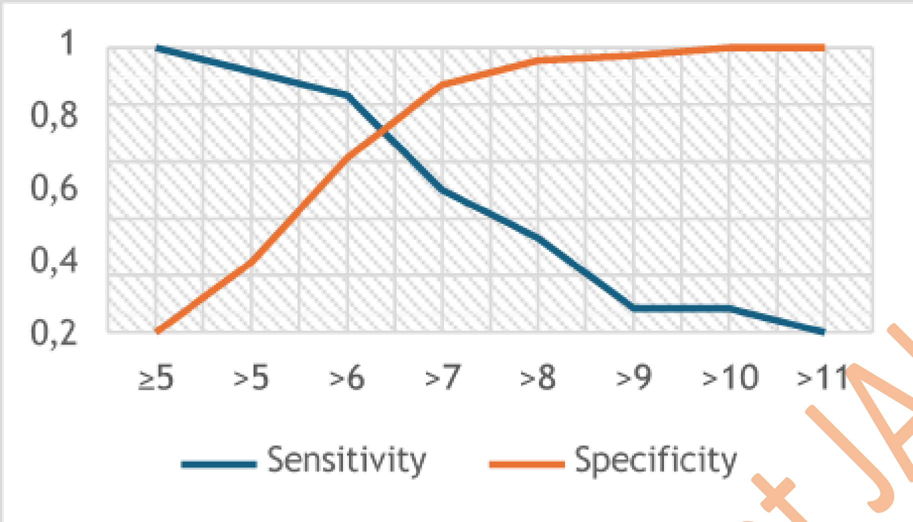

Figure 1. Graph of COPUR score cutoff for sensitivity and specificity

Table 4. Distribution of COPUR score performance at each cutoff.

COPUR score	Sensitivity	Specificity	Youden index
≤5	1	0	0.000
≥6	0.9167	0.2477	0.164
≥7	0.8333	0.6147	0.448
≥ 8	0.5	0.8716	0.372
≥ 9	0.3333	0.9541	0.287
≥ 10	0.0833	0.9725	0.056
≥ 11	0.0833	1	0.083
≥ 12	0	1	0.000

COPUR: Colorado Pediatric Airway Score

Table 5. Final logistic regression model for predicting difficult intubation

Variable	B coefficient	SE	p-value	OR	(95% CI)
Uvula (1)	1.206	0.717	0.093	3.341	0.819-13.63
Uvula (2)	3.045	1.16	0.039	21.0	2.155-204.614
Constant	-3.045				

SE: standard error; OR: odds ratio; CI 95%: 95% confidence interval
P<0.05 denotes statistical significance

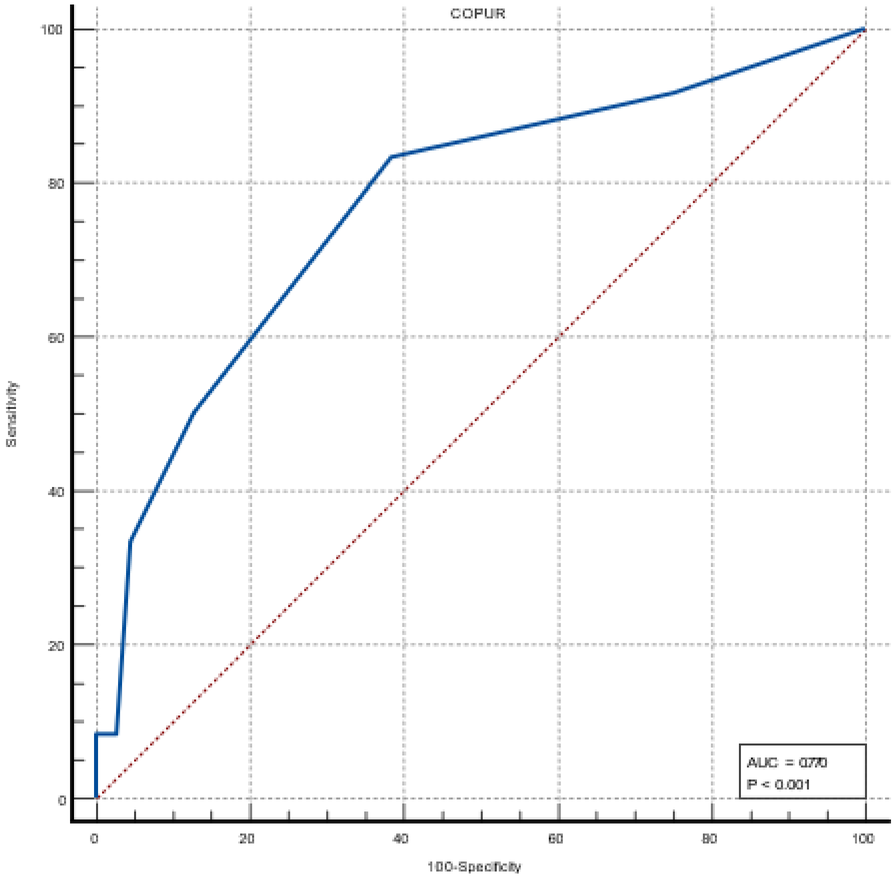

Figure 2. ROC Curve of COPUR score for predicting difficult intubation

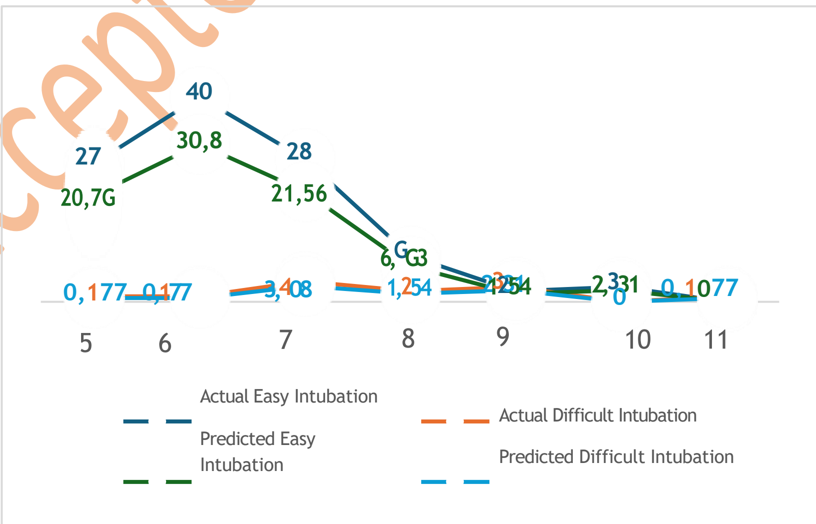

Figure 3. The goodness-of-fit test using the Hosmer-Lemeshow method. Chi-Square calibration value of 2.98 with a p-value of 0.561

DISCUSSION

Among the 121 study subjects (Table 1), 15.7% of children were predicted to have difficult intubation based on the original COPUR score using a cut-off of ≥8. However, the actual incidence of difficult intubation, defined as an IDS score >5, was observed in 9.92% of cases. This discrepancy differs from the findings of Aggarwal et al.[3], who reported an incidence of 2% for difficult intubation (IDS >5) in a study population of 100 pediatric patients. The observed difference may be attributed to variations in subject characteristics, age distribution, and case variability at Cipto Mangunkusumo Hospital.

A stratified analysis based on age groups revealed that younger children exhibited a lower incidence of difficult intubation. The incidence was 5.8% in children aged <2 years, 12.8% in children aged 3–5 years, and 13.3% in children aged >5 years. Subjects older than 2 years were found to have a 2.4 to 2.5 times higher risk of difficult intubation compared to those aged 1–2 years. However, this association was not statistically significant ($p > 0.05$).

Our study revealed that the COPUR score demonstrated good calibration and discrimination ability. Calibration was assessed using the Hosmer-Lemeshow test (Figure 3), yielding a p-value of 0.584 ($p > 0.05$), indicating that the COPUR score is well-calibrated (i.e., a good fit) for predicting difficult intubation. Discrimination, which evaluates a scoring system's ability to distinguish between subjects who will and will not experience the outcome, was assessed using the area under the curve (AUC) (Figure 2). The AUC value was 0.770 (95% CI: 0.685–0.842), indicating a moderate to good level of discrimination.

The optimal cut-off point for the COPUR score was determined to achieve the best balance between sensitivity and specificity. As shown in Figure 1, the selected cut-off was 7, as it provided optimal sensitivity while maintaining acceptable specificity. With a cut-off of 7, the COPUR score demonstrated a sensitivity of 83.3% (95% CI: 51.6–97.9) and a specificity of 61.47% (95% CI: 51.7–70.6), albeit with relatively wide confidence intervals. Meanwhile, the original cut-off of ≥8 resulted in a sensitivity of 50% and a specificity of 87.16%. A COPUR score of 7 was able to correctly predict 83% of difficult intubation cases, while also effectively ruling out cases where intubation difficulty was unlikely.

For a COPUR score of ≥7, the PPV was 19.24% (95% CI: 14.41–25.2), while the NPV was 97.1% (95% CI: 90.35–99.17). The positive likelihood ratio (LR+) for a COPUR score of ≥7 was 2.16 (95% CI: 1.53–3.06), and the negative likelihood ratio (LR-) was 0.27 (95% CI: 0.076–0.97). A COPUR score of ≤6 accurately predicted the absence of difficult intubation with a 97% probability, whereas a COPUR score of ≥7 correctly identified difficult intubation cases in 19% of cases.

Airway assessment using a scoring system is expected to aid decision-making in anticipating airway management challenges. Relying on multiple independent variables for airway evaluation may lead to confusion, as these variables do not always converge to provide a clear prediction of potential intubation difficulty. The complexity of a scoring system also affects its practical application; simpler, more straightforward, and efficient assessments are easier to implement in daily clinical practice. The COPUR score offers a more practical approach as it consists of easily assessable variables, integrates both patient history and physical examination, does not require specialized equipment, and can be performed bedside during a pre-anesthesia visit. In this study, the COPUR score used as an independent variable with a cut-off of 7, was found to be statistically significant. A COPUR score of ≥7 was associated with a 7.9-fold increased risk of difficult intubation, with a p-value <0.05, indicating statistical significance.

We found that 85.96% of patients had a normal chin (chin score = 1), while 12.4% had a small chin (chin score = 2). Additionally, one patient (0.8%) had a recessive chin (chin score = 3), and one patient (0.8%) had an extremely hypoplastic chin (chin score = 4). Patients with a small chin had a 1.6 times higher risk of difficult intubation compared to those with a normal chin; however, this association was not statistically significant (p > 0.05).

For the mouth opening variable, 97.5% of patients had a score of 1, indicating a mouth opening of >40 mm. No patients in the study population exhibited severe mouth-opening restriction (<20 mm). Among patients with a mouth opening >40 mm, 89.8% did not experience difficult intubation. Additionally, all patients with a mouth opening of 20–40 mm were successfully intubated without difficulty.

This study also found that patients with a history of difficult intubation or symptoms of obstructive sleep apnea (OSA) had a 5.97 times higher risk of difficult intubation compared to those without such a history. This finding aligns with several observational studies and a meta-analysis by Nagappa et al.[18], which reported that adult patients with OSA had a 3.46 times higher risk of difficult intubation compared to those without OSA.[18,19]

In the multivariate analysis, the uvula variable was identified as the strongest predictor of difficult intubation. This finding is consistent with previous research by Santos et al.[20], which analyzed 100 pediatric patients and demonstrated a significant correlation between the Mallampati score and the degree of laryngoscopy difficulty (p = 0.0001). The Mallampati score has been validated as a reliable predictor of laryngoscopy difficulty in pediatric patients.[21,22,23] Additionally, studies in adult populations further support this relationship. Research by Nasa et al.[24] and Aggarwal et al.[3] reported a significant association (p < 0.005) between difficult intubation (IDS score >5) and Mallampati class 3–4.

This study has several limitations. Firstly, it was conducted at a single center, which may limit case variability and generalizability, as the study population only represents the characteristics of patients at Cipto Mangunkusumo Hospital. Secondly, airway assessment in pediatric patients is highly dependent on patient cooperation, which is influenced by age. Children under 3 years old often present greater challenges in evaluating certain variables, particularly the uvula assessment. Additionally, while the COPUR score is widely used in clinical practice, the original publication lacks a detailed description of how each variable is assessed. Furthermore, there are no published validation studies for the COPUR score, which may result in variability in interpretation depending on the examiner, potentially affecting objectivity.

Further multicenter studies across various hospital types with larger sample sizes are needed to capture a broader range of cases, ensuring that the findings can be generalized to a wider population. Screening for airway difficulty in pediatric patients using the COPUR score may be considered for routine clinical practice, particularly in predicting intubation difficulty in children aged 1–8 years. At Cipto Mangunkusumo, the application of the COPUR score with a cut-off of ≥7 could be a valuable tool in anticipating difficult intubation. Further research should also focus on expanding the applicability of the COPUR score to infants (<1 year old), particularly in high-risk patients, to enhance its clinical utility in the pediatric population.

CONCLUSION

The proportion of patients with a COPUR score ≥8 who experienced difficult intubation was 15.7%, while the overall incidence of difficult intubation in this study was 9.92%. A COPUR cut-off score of ≥7 provided the highest sensitivity (83.3%) and specificity (61.47%) in this population, compared to the original cut-off of ≥8, which had a sensitivity of 50% and specificity of 87%. The COPUR score demonstrated adequate discrimination and good calibration, confirming its reliability as a predictor of difficult intubation in children aged 1–8 years.

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