

Is Airway-Related Pathology the Main Risk Factor for Difficult Intubation in Children Under 6 Years Old?

Sandra Galve-Navarro, PhD¹, Francisca Munar-Bauzá, PhD^{1,2}, Cristina Muro-Castro, MD¹, Irene García-Martínez, MD¹, Susana Manrique-Muñoz^{1,2}, PhD, and Miriam de Nadal, PhD^{1,2}

¹ Department of Anesthesiology, Vall d'Hebron Hospital Universitari, Vall d'Hebron Hospital Campus.

² Department of Surgery, Univ Autònoma Barcelona, Bellaterra, Spain.

Introduction: Evaluating pediatric airways is challenging, particularly in identifying those at risk for difficult intubation, which is often linked to craniofacial malformations. Limited cooperation from preschoolers further complicates this evaluation.

Objective: To evaluate the predictive accuracy of the Arné Score in identifying risk factors for difficult intubation in preschoolaged children (under 6 y) and develop a model to prevent difficult laryngoscopy and intubation. Secondary objectives include determining the incidence of difficult intubation and the appropriate age for preanesthetic airway assessments.

Methods: This retrospective observational study analyzed 1385 patients aged 0 to 16 years, all undergoing general anesthesia and tracheal intubation in 2018 at a tertiary hospital in Barcelona. Among them, 708 were under 6 years. Predictive tests included the Arné Score, with difficult intubation defined by Cormack-Lehane scores, intubation attempts, and alternative device use. Logistic regression analyzed predictors with significant odds ratios.

Results: Unrecorded Mallampati test values were common in children under 6 years (99.04%). Of those without a history, 8.07% faced intubation difficulties, compared with 50% with a history. Relative risk was 6.23, and the odds ratio was 11.46. Among 202 classified with airway difficulties, 82.67% had no intubation issues. Statistically significant associations highlighted greater risks for those with a difficult intubation history. Conclusions: Arné Score tests are impractical for children under 6. If no history or airway pathology exists, there's a 95.14% chance of successful intubation. The history of difficult intubation increases risks more than airway pathology alone.

In the operating room, induction and intubation are critical moments. While most intubations proceed without incident, unexpected difficult airways (DA) pose significant risks to patients. Intubation issues account for approximately one-third of all anesthesia-related deaths and serious sequelae. Historically, many anesthesiologists have regarded difficult intubation as a minor inconvenience, often addressing it without formal

protocols or guidelines. However, increasing reports have highlighted the serious morbidity and mortality associated with improperly managed difficult intubations.

DA results from a complex interplay of patient factors, clinical environment, and the skills of the physician's assistant. Accurate data collection and communication are essential for analyzing this interaction. In 2003, the American Society of Anesthesiologists (ASA) introduced clinical practice guidelines for managing difficult airways, with updates in 2013 and 2022.¹ These guidelines define DA as a clinical situation where a trained anesthesiologist encounters difficulty or failure in facemask ventilation, laryngoscopy, supraglottic airway ventilation, tracheal intubation, extubation, or invasive airway management.

To identify patients who might present challenges with direct laryngoscopy (DL), various preoperative measures for noninvasive ventilation have been described. While these tests often show high specificity and negative predictive value, their sensitivity and positive predictive value are typically low, partly due to the low prevalence of difficult airways. In addition, variability in observer measurements, ill-defined variables, and anatomic differences across races and ages further limit their effectiveness. Research has demonstrated the low predictive capacity of these measures.

Some tests are included in the Arné Score,² a widely disseminated table that uses logistic regression to assign a score based on clinical criteria, establishing a threshold for difficult intubation in adults. The Catalan Society of Anesthesiology, Resuscitation, and Pain Therapy (SCARTD) recommended these tests in its 2008 guidelines³ but revised the criteria in its 2020 update.

Despite these developments, most DA studies and guidelines focus on adult populations and are applied to pediatric patients without scientific validation. Pediatric studies are often reviewed that extrapolate adult data or are observational without predictive power analysis. These studies typically focus on populations with known DA risk factors, such as craniofacial deformities or a history of difficult intubation. However, pediatric anatomy changes with age, and preschoolers (under 6 y) have limited cooperation in predictive tests. Thus, the only reliable predictors for this age group are patient medical history, specifically, a history of difficult intubation and airway disease.

This research aims to identify predictive factors for managing DA in preschool-aged patients and establish an age threshold for preanesthetic assessment. Understanding these factors can improve planning and reduce the risks of airway trauma and hypoxia from repeated intubation attempts. This study hypothesizes that the predictive tests for identifying difficult intubation from the Arné Score are not valid for the preschool pediatric population. Through logistic regression, we will create models to identify the most predictive factors in this population, aiming for minimal variables to ensure practicality.

MATERIALS AND METHODS

Study Design and Setting

This is a retrospective observational study conducted to assess difficult airway (DA) predictive factors in pediatric patients (ages 0-16 y) at Hospital Universitari Vall d'Hebron (HUVH) during 2018. The study follows the methodology outlined in the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines. Approval was obtained from the Drug Research Ethics Committee and the HUVH Research Project Commission on March 29, 2019, for the PR (AMI) 78/2019 research project titled "Anàlisi multivariant dels factors predictius de la VAD en el pacient pediàtric" ("Multivariate analysis of predictive factors of DA in the pediatric patient"). All collected data were encoded to ensure patient privacy rights compliance.

Participants

This study included all procedures performed on pediatric patients aged 0 to 16 years who underwent general anesthesia and tracheal intubation (TI) from January 1 to December 31, 2018, at the Hospital del Nen i de la Dona de l'HUVH operating room. A total of 1385 patients were included, of which 716 were under the age of 6 years. (Supplemental Table 1, Supplemental Digital Content, <http://links.lww.com/SCS/H615>: Characteristics of the study participants). Patients intended for general anesthesia with a supraglottic airway device or sedation were excluded unless they later required general anesthesia with TI. Also excluded were those who entered the operating room with an endotracheal tube or had a tracheotomy in situ.

Data Collection

Data were collected from the preanesthesia assessment document and the procedure's paper register, included in the patient's Electronic Medical Record and/or SAP Assistencial surgical procedure document (Argos, Barcelona) managed by IBM, a healthcare information system of the Institut Català de la Salut. Recorded information included demographic and reference characteristics, preoperative assessment factors, and anesthetic procedure details.

Predictive Factors and Variables

Predictive factors for DA were those described in the Arné Score and recommended by the SCARTD: history of difficult intubation, difficult intubation-related disease,⁴ modified thyromental distance, mouth opening, maximum head and neck motion, and Mallampati score. Variables related to intubation difficulty were collected from the anesthesia document where intubation data are systematically recorded, including the Cormack-Lehane classification system value, number of intubation attempts, and the use of another type of device (Supplemental Table 2, Supplemental Digital Content, <http://links.lww.com/SCS/H615>). All preanesthetic assessments and intubations were performed by anesthesiologists from the HUVH Anesthesiology Service (a medical assistant with experience in pediatric DA or a third-year or fourth-year resident physician under supervision).

Definition of Difficult Intubation

Following Karkouti et al,⁵ difficult TI using direct laryngoscopy was defined based on the Cormack-Lehane classification and the number of intubation attempts. TI was categorized as "easy" if the number of intubation attempts plus the CormackLehane grade was ≤ 4 , and "difficult" if the number was > 4 . Patients were also categorized as "difficult" if any device other than direct laryngoscopy was used. An intubation attempt was defined as the insertion of the laryngoscope into the oropharynx with an attempt to pass the endotracheal tube through the vocal cords.

Statistical Analysis

To confirm the difficulty of applying predictive tests requiring preschool-aged patient cooperation (under 6 y), an analysis of missing data was performed. Nonregistered Mallampati test values were analyzed by age group using a χ^2 test with Yates' correction. For subsequent validation of predictive tests and model creation, the 2 age groups were divided.

The incidence of difficult intubation was studied by calculating absolute and relative frequencies and the percentage by age, with a 95% confidence interval estimated using a χ^2 test. Differences by age groups were established using the Fisher test, with the odds ratio calculated.

The relationship between predictive tests and difficult intubation was evaluated using contingency tables and χ^2 tests. Group comparisons were performed globally using the Fisher test and by pairs to establish dichotomous variables. Relative risk and odds ratio were used to determine the influence of variables on intubation difficulty.

Logistic regression was used to create multivariate models through forward selection, retaining the most predictive factors (those with the lowest SE and highest coefficient of determination) with as few variables as possible. Statistical tests, including the likelihood ratio, score, and Wald test, were used to assess model validity and quality. Exclusion significance values ($P < 0.05$) were employed to compare models using the ANOVA test.

For children under 6 years, since only 2 predictive factors are involved, a predictive scale was not established; instead, the probability of difficult intubation was predicted with 4 possible combinations.

RESULTS

Of the 5372 procedures performed in the operating room, those not meeting the inclusion criteria were successively eliminated: patients over 16 years old at the time of surgery (1928), surgeries without TI (1999), cases without all necessary documents (50), and 10 cases involving developmental and learning disabilities.

When analyzing missing data (Fig. 1), we observed 517 cases where participatory predictive test results were not collected. The distribution of unrecorded Mallampati test values by age showed that most cases involved patients under 6 years (Fig. 2).

Specifically, 99.04% of cases under 6 years old had no Mallampati assessment file, compared with 0.74% of cases over 6 years old.

The incidence of difficult intubation, defined by the addition of the Cormack-Lehane classification system value and the number of laryngoscopy attempts being ≥ 4 , was 9.55% (95% CI: 7.99-11.15; $P < 2.2e - 16$). Among preschool-aged patients (under 6 y), 61 of the 708 observed cases were difficult intubations, representing an incidence of 8.61% (95% CI: 6.70 – 10.99; $P < 2.2e - 16$). There was no significant difference in the incidence of difficult intubations between the two age groups.

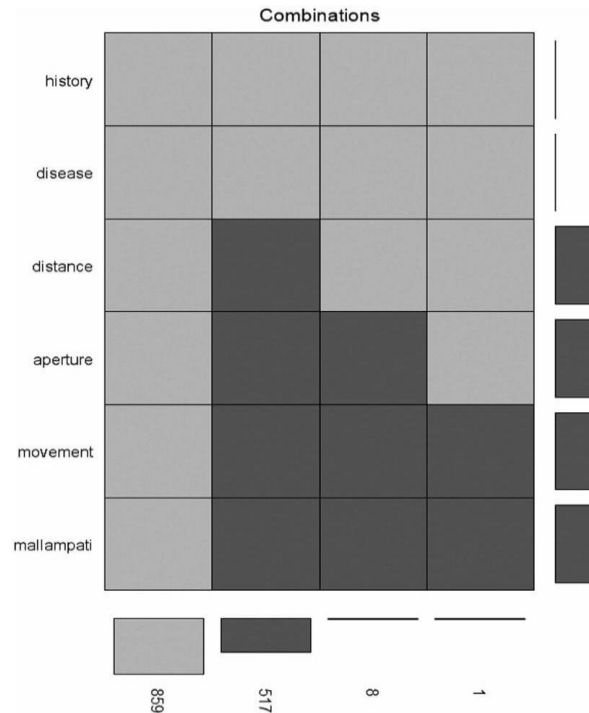


FIGURE 1. Representation of current and missing data. The present data is shown in light color, and the missing data is shown in dark color for the factors that make up the Arné scale. The absolute frequencies of the different combinations of missing data for the variables are indicated in numbers.

Among the cases with a history of difficult intubation, 50% presented difficult intubation, while the remaining 50% did not. Among those with no history, 8.07% encountered intubation difficulties, compared with 50% among those with a history of difficult intubation (Supplemental Table 3, Supplemental Digital Content, <http://links.lww.com/SCS/H615>). There was a significant association between a history of difficult TI and the occurrence of difficult TI (Fisher Test, $P = 0.0007$). In this age group, the relative risk was 6.23 (95% CI: 3.19-12.16; $P < 0.001$), and the odds ratio was 11.46 (95% CI: 3.22-40.79; $P < 0.001$).

Among the 716 observations, 202 were classified as having DA, accounting for 28.21% of all surgical procedures (95% CI: 24.97 – 31.69%). In this group, 82.67% of patients classified as pathologic did not experience difficult intubation. There was a statistically significant association ($P = 1.798e - 07$), with an odds ratio of 3.87 (95% CI: 2.26-

6.62; $P < 0.001$) and a relative risk of 3.37 (95% CI: 2.09-5.45; $P < 0.001$) (Supplemental Table 4, Supplemental Digital Content, <http://links.lww.com/SCS/H615>).

Predictive Model of Intubation

Both history and DA-related disease were highly significant in the logistic model (Supplemental Table 5, Supplemental Digital Content, <http://links.lww.com/SCS/H615>), with very low P values ($P = 0.000$), demonstrating the importance of both variables in explaining the dependent variable. ANOVA confirmed the significance of the included terms, with $P = 0.000$ for each term. According to the model, the logarithm of the odds of a child having difficult intubation was positively related to a history of difficult intubation (partial coefficient: 2.31), a significant relationship. There was also a significant positive relationship between the odds logarithm of difficult intubation and the presence of a DA-related disease ($P = 0.000$). The model was significant, and the contributions of the two predictors were also significant (Residual difference: 34.55; $df: 2$; P -value: $3.128921e-08$).

Since only 2 predictive factors were involved, establishing a predictive scale was unnecessary. The likelihood of not having difficult intubations was predicted using the four possible combinations. The absence of both predictors resulted in a 95.14% likelihood of not experiencing difficult intubation. The presence of both factors implied a 65.98% likelihood of difficult intubation. A history of difficult TI carried more risk of difficult intubation than a DA-related disease. Supplemental Table 6, Supplemental Digital Content, <http://links.lww.com/SCS/H615>, shows the probabilities of these predictions using the adjusted generalized linear model.

DISCUSSION

The attempt to validate the tests that constitute the Arné Scale in pediatric patients has confirmed that the only predictive elements for children under 6 years of age are a history of difficult intubation and airway-related disease. The remaining factors are not applicable in daily clinical practice and, therefore, cannot be assessed.

Given the multifactorial etiology of difficult intubation, it is logical to assume that success can result from a simultaneous analysis of various predictive tests aimed at improving the individual predictive capacity. Efforts have been made to create composite variables to enhance difficult intubation screening, but the addition of variables did not increase sensitivity, potentially due to the myriad factors involved. One of the objectives of logistic regression is to establish a model and obtain an equation to predict or calculate risk with validity and precision. This study aimed to validate the Arné score for pediatric patients, modified to enhance clinical applicability.

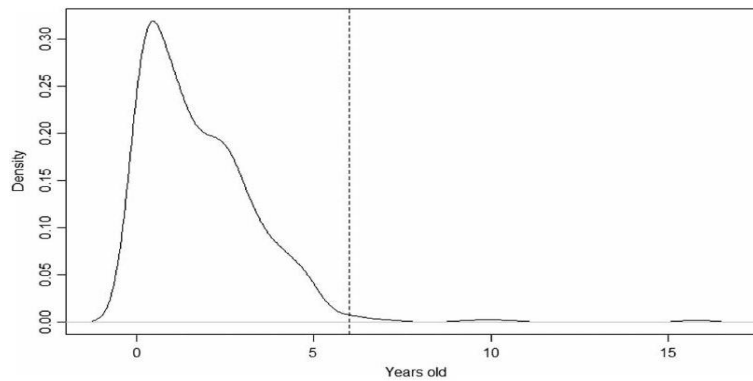


FIGURE 2. The distribution of cases without a response in the Mallampati variable according to age.

In preschool children, the lack of cooperation in performing certain predictive tests limits the predictive model to 2 factors: history of difficult intubation and DA-related disease. The coefficients indicate that a history of difficult intubation poses a greater risk of difficult TI than a diagnosis of DA-related disease. This might be because, for many patients, this is their first surgery, and the absence of history correlates with low sensitivity. Conversely, having experienced a difficult intubation significantly increases the risk of another occurrence for the same reason, with almost 100% specificity.

The preanesthetic assessment document in use at the time of the study followed the SCARTD criteria based on the Arné Score. This allowed the assignment of a numerical value with a threshold for predicting a difficult airway. The accessibility and standardized criteria of these factors make them useful for this study. Thus, these tests can be validated or not as indicators of the risk of difficult intubation in pediatric patients.

https://seguretatdelspacients.gencat.cat/web/.content/minisite/seguretatpacients/professionals/documents/arxiu/viaaeria_avaluacio.pdf

Heinrich's study,⁶ involving 11,219 pediatric anesthetic procedures, showed that the risk of difficult laryngoscopy is significantly higher in patients younger than 1 year, low-weight patients, and those with ASA III and IV. If the Mallampati score could be obtained, it was a reliable predictor of difficult laryngoscopy, but no other factors were analyzed. Tobias,⁷ in an extensive review of preoperative anesthetic assessment in pediatric surgery, acknowledged that while various screening tests have been proposed for adults, none exist for pediatric patients. The statistical analysis conducted in this study validates the tests included in the Arné score and suggests modifications to some of the criteria. There is no other exhaustive analysis in the literature that modifies the necessary criteria.

Analysis of Predictive Factors of Difficult Airway

According to this study, the presence of previous difficult intubation increases the risk by 11.46 times in children under 6 years. The NEAR4KIDS study⁸ reported a value of 1.83 if the practitioner had experience, which was not statistically significant for inexperienced practitioners. Sensitivity, specificity, and negative predictive value in both studies may overlap within their confidence intervals. However, the positive predictive

value in this study is substantially higher than in NEAR4KIDS (22% vs. 65%). These analyses, although necessary, are not conclusive.

Among the predictive factors of DA, the dichotomous variable "difficult intubation-related disease" with a YES/NO value was included. This accounted for 28.21% of all surgical procedures (95% CI: 24.97-31.69%). This percentage is extraordinarily high, likely reflecting the hospital's specialization in neonatal, maxillofacial, and pediatric neurosurgery and its status as a reference center for complex craniofacial pathologies as part of the European ERN CRANIO network. This higher intervention rate increases the weight of this factor in DA prediction. The wide variety of syndromes included should be reviewed to accurately determine the incidence of intubation difficulties. For example, Gregory ⁹ reported that only 3% of 800 patients undergoing cleft lip and palate repair had a difficult laryngoscopic experience. Similarly, the prevalence of sleep apnea syndrome, estimated at 1% to 3%, is not clearly associated with intubation difficulties despite being classically linked to airway management challenges. Tonsillectomy and adenoidectomy, frequent pediatric surgeries, are also not clearly linked to intubation difficulties. Reviewing classifications of DA-related disease is essential to establish management algorithms tailored to expected complications and anatomic abnormalities.

Limitations of the Study and Proposals

The study's limitations include the nonrepresentative age and characteristics of the pediatric population studied. To generalize the data to the entire population, a study encompassing hospitals of varying complexity levels is needed.

A prospective clinical study could standardize data collection, establish clear inclusion criteria, and classify predictive tests. It should also include variables such as intubation time and anesthesiologist experience, which can be confounding factors. Prospective studies could refine predictive tests and create more precise logistic models or apply artificial intelligence algorithms.

The study's limitations include its retrospective nature and the specific population studied, which may not be representative of all pediatric patients. Future research should involve prospective studies across multiple hospitals to generalize findings and refine predictive models. Incorporating variables such as intubation time and anesthesiologist experience could further improve predictive accuracy.

The large data set can address other research questions: the influence of obstructive sleep apnea syndrome on DA, re-evaluation of its classification as a related DA disease, and the appropriateness of current measures such as thyromental distance. In addition, the impact of craniofacial malformations on pediatric intubation warrants further exploration.

CONCLUSIONS

This study aimed to validate the predictive factors of difficult intubation in pediatric patients, particularly focusing on children under 6 years old. Our findings indicate that, in this age group, the only reliable predictive factors for difficult intubation are a history of difficult intubation and the presence of airway-related disease. Other predictive tests used

for adults are not applicable or practical in the preschool age in a clinical setting due to their limited cooperation.

Among the significant predictors, craniofacial malformations are notably relevant as they represent a subset of airway-related diseases that can considerably increase the risk of difficult intubation. The presence of these malformations often complicates airway management, emphasizing the importance of a thorough preoperative assessment. Children with craniofacial abnormalities, such as cleft lip and palate or other congenital anomalies, should be closely monitored and prepared for potential difficulties during intubation.

The logistic regression model developed in this study highlighted the significant contributions of a history of difficult intubation and DA-related diseases, including craniofacial malformations, in predicting difficult intubation. A history of difficult intubation poses a higher risk compared with other DA-related diseases. This suggests that clinical assessments for preschool children should prioritize these factors to improve intubation planning and reduce the risks associated with difficult intubations, such as airway trauma and hypoxia.

The study also underscores the need for specific and standardized predictive tests tailored to the pediatric population, especially considering the anatomic and physiological differences in children with craniofacial malformations. The reliance on adult-based predictive tests is insufficient for this demographic. The statistical analysis validated the Arné score's applicability to some extent but indicated necessary modifications to enhance its relevance for pediatric patients with craniofacial anomalies.

In summary, understanding and accurately predicting difficult intubation in the preschool age, particularly those with craniofacial malformations, is crucial for improving patient outcomes. This study provides a foundation for developing more effective predictive tools and clinical guidelines to manage DA in pediatric patients, ensuring better preparedness and safety during airway management.

The authors report no conflicts of interest.

Supplemental Digital Content is available for this article. Direct URL citations are provided in the HTML and PDF versions of this article on the journal's website, www.jcraniofacialsurgery.com.

REFERENCES

1. Apfelbaum JL, Hagberg CA, Connis RT, et al. 2022 American Society of Anesthesiologists Practice Guidelines for management of the difficult airway. *Anesthesiology* 2022;136:31-81
2. Arné J, Descoins P, Fusciardi J, et al. Preoperative assessment for difficult intubation in general and ENT surgery: predictive value of a clinical multivariate risk index. *Br J Anaesth* 1998;80:140-146
3. Valero R, Mayoral V, Massó E, et al. Evaluación y manejo de la vía aérea difícil prevista y no prevista: Adopción de guías de práctica. *Rev Esp Anestesiología Reanimación* 2008;55:563-570
4. Andreu E, Schmucker E, Drudis R, et al. Algoritmo de la vía aérea difícil en pediatría. *Rev Esp Anestesiología Reanimación* 2011;58:304-311
5. Karkouti K, Rose DK, Wigglesworth D, et al. Predicting difficult intubation: a multicenter perioperative outcomes group study. *Anesthesiology* 2000;93:1467-1476
6. Heinrich S, Birkholz T, Ihmsen H, et al. Incidence and predictors of difficult laryngoscopy in 11,219 pediatric anesthesia procedures. *Pediatric Anesthesia* 2012;22:729-736
7. Tobias JD. Preoperative anesthesia evaluation. *Semin Pediatr Surg* 2018;27:67-74
8. Graciano AL, Tamburro R, Thompson AE, et al. Incidence and associated factors of difficult tracheal intubations in pediatric ICUs: a report from National Emergency Airway Registry for Children: NEAR4KIDS. *Intensive Care Med* 2014;40:1659-1669
9. Gregory GA, Andropoulos DB. *Gregory's Pediatric Anesthesia: Fifth Edition*. Oxford: UK Wiley; 2012