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# MANAGEMENT OF THE DIFFICULT AIRWAY IN THE PEDIATRIC PATIENT — REVIEW OF EXISTING SCALES

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## ABSTRACT

There are numerous anatomical, physiological, and clinical differences between pediatric and adult airway management. Airway obstruction in children is unquestionably a stressful situation for the medical staff and the patient's family. Therefore, caregivers must be able to accurately assess the risk of such an occurrence.

To date, there is no consensus on a single ideal pediatric airway assessment scale that could help identify children with the highest risk for intubation-related adverse events. Instead, a few classifications and methods were proposed, with some employing the same techniques proven effective for adults and others emphasizing the differences in the pediatric population. This article compares the data used to support the use of various perioperative airway assessment techniques in pediatric patients. The majority of these remedies rely on anatomical measurements, bedside tests, and in-depth patient histories.

This narrative review highlights the need for standardized and reliable pediatric airway assessment scales and stresses the significance of structured airway assessment in pediatric patients.

KEY WORDS: pediatric airway assessment; pediatric intubation; difficult airway; airway management

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## INTRODUCTION

Airway management in pediatric patients has many anatomical, physiological, and clinical differences compared to the adult population [1]. For example, analysis of closed pediatric and adult anesthesia malpractice claims shows a considerably different distribution of respiratory events — they are more common in children (43% vs 30% in adult claims; P < or = 0.01) and have higher — mortality rates (50% vs 35% in adult claims; P < or = 0.01) [2]. The difficult airway in children is an undoubtedly stressful situation for the medical team [3] and the patient's family. Therefore, caregivers must be able to assess the risk of this kind of event thoroughly.

The PeDI registry suggested a range of 2–5 difficult tracheal intubations per 1000 anesthetized children.

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The first intubation attempt was successful in only 30% of cases in the registry cohort. However, 98% of the patients were eventually intubated [4]. A recent APRICOT study analyzed more than 31 000 anesthetic procedures in Europe and found that 0.9% of patients required three or more attempts for tracheal intubation. Difficult intubation was reported in 0.28% of patients, with incidence significantly higher in neonates [1%, 95% confidence interval (CI): 0–2.2%] and infants (1.1%, 95% CI: 0.6–1.6%) than in any other age group, proving that the youngest population is at highest risk for airway management problems [5].

Many catastrophic complications during airway management in pediatric patients may be preventable with proper assessment, planning, and execution [6]. In the general population, perioperative airway assessment has become crucial in predicting difficult intubation. Multiple assessment tools have been proposed for the general population, and their usefulness was confirmed in extensive studies. For example, Rose and Cohen proved that if four characteristics (including thyromental distance, mouth opening, neck movement, and hypopharynx visualization) were typical, the chance for easy tracheal intubation was 95.2%. However, if only one of these parameters was abnormal, the ease to intubate was significantly lower — e.g., only 62.4% of patients with limited mouth opening had easy intubation, demonstrating the importance of a multi-level approach in perioperative risk calculation [7].

Nevertheless, bedside airway assessment tests tend to have low sensitivity, moderate specificity, and high variability. Moreover, their accuracy vastly depends on the patient's efforts and cooperation [1]. Therefore, it may be significantly limited in the pediatric population, especially in neonates and infants, who are already at higher airway management risk in the first place.

To this day, no consensus for one ideal pediatric airway assessment scale could help spot children with the most important chances for intubation-related undesired events. Instead, a few methods and classifications were proposed, some using the same techniques proven effective in adults and some highlighting the differences in the pediatric group. Most of these solutions rely on anatomical measurements, bedside tests, and detailed history taking. The following review outlines the techniques of perioperative airway assessment in children, comparing the data used to support their use in the pediatric population.

## MATERIAL AND METHODS

A comprehensive literature search was conducted up to May 2023 to identify relevant studies on the techniques of airway assessment in pediatric patients. Electronic databases, including Medline (PubMed), Embase, Scopus, Web of Science, and Cochrane Central Register of Controlled Trials (CENTRAL), were searched using appropriate search terms such as 'pediatric airway assessment', 'pediatric intubation', and 'difficult airway'. The search was limited to articles published in English up to the search date.

Two independent researchers reviewed the selected studies, and data relevant to the objectives of this narrative review were extracted. The extracted data included study characteristics (e.g., study design, sample size), patient characteristics (e.g., age, comorbidities), and outcomes related to airway assessment techniques. Any discrepancies or disagreements were resolved through discussion and consensus.

## RESULTS

### Risk factors — the role of history taking and clinical exam

Difficult airways can be anticipated and unanticipated. The latter situation is undoubtedly more stressful for medical professionals and prone to errors, as teams often need to be prepared and ready with equipment. Although unanticipated tracheal intubations have more severe complications and require more attempts, studies show that most difficult airways in children are, in fact, predictable. Anticipated situations may result from congenital syndromes and anatomical airway dysfunctions [8, 9]. In addition, children with pre-existing respiratory risk factors have an increased likelihood of critical respiratory events (regardless of the airway device used). Therefore, such factors require better preoperative assessment and planning [5].

The detailed clinical exam should evaluate the symmetry of the head, face, and neck, the presence or absence of oral pathologies, oral hygiene, or adequacy of neck movements. Specific changes might be due to temporary conditions, including facial burns, oral tumors, or head and neck swelling. However, many pediatric patients undergoing anesthesia are children with congenital syndromes. Some of them have an impact on airway management, as they are associated with features like limited neck length or mobility (Klippel-Feil syndrome), micrognathia, tongue retraction, and mandibular hypoplasia (Pierre-Robin syndrome and Treacher Collins syndrome), or macroglossia and small mouth opening (Beckwith-Wiedemann syndrome and Goldenhar syndrome). In addition, multiple dysmorphic features might be present in the same patient — in trisomy 21, macroglossia, short neck, and atlanto-axial instability often coexist. What is more, some abnormalities affecting airway management — such as subglottic stenosis in Down syndrome or respiratory secretions in mucopolysaccharidosis – are not easily visible and may require assessing the difficulty of airways based on snoring, wheezing, sleep apnea, or other signs noted by the parents [1].

Perioperative assessment should include observing the face from the front and the side to evaluate the chin and lower and upper teeth alignment. In addition, visualizing the child from the lateral profile prevents missing subtle signs of mandibular hypoplasia and can detect the most potentially difficult intubations [10, 11].

Taking airway-focused history helps identify respiratory issues encountered during previous admissions [6]. Nevertheless, as some parents may not recall or understand the details, reviewing medical documentation in search of the type of airway management method, size of the equipment, number of attempts, and obtained laryngoscopic views should help medical providers determine previous dangerous airway events. It is equally essential for practitioners to include information about any difficulties encountered during airway management in their medical notes, as they can have crucial meaning for further teams caring for the patient.

Some risk factors depend more on the environment or current health status — passive smoking and recent upper airway infections increase the risk of laryngospasm during anesthesia [1]. The influence of surgery type was also noted, as children undergoing oromaxillofacial, otolaryngologic, or cardiac surgery are at higher risk of difficult intubation. Airway management issues are also more common in patients with ASA III or IV — therefore, with more significant health issues in the first place [6]. Conclusions from the PeDI registry showed that patients weighing less than 10 kilograms had more tracheal intubations with complications than uncomplicated ones [4]. Unlike in adult patients, no evidence was found for factors like increased BMI or neck circumference to predict difficult intubation in the pediatric population [6, 8]. In children, the risk is higher for underweight, not overweight patients — age-matched BMI lower than the 10$^{th}$ and 3$^{rd}$ percentile correlated with significantly increased incidence of difficult laryngoscopy [12].

Yet not every pediatric patient at significant risk of the difficult airway has any pathologies at all — children might be generally healthy and well-developing, but some factors are simply due to demographics. Age is crucial, as the younger the patient is, the higher the risk of complications. However, although adult male patients are at risk of difficult intubation, there is no effect of gender in any pediatric group [12].

## Laryngoscopy and Cormack-Lehane Test

Cormack and Lehane Classification was proposed in 1984 and was based on the view of indirect epiglottis laryngoscopy. The Cormack-Lehane grading scale is presented in Figure 1. Cases with grades 3 and 4 are considered as difficult laryngoscopy, but they rarely happen [1]. Although in difficult general, laryngoscopy might be even 2–20-fold less common in the pediatric population than in adults, it remains a significant issue in the youngest group. At the same time, 5% of infants have a Cormack and Lehane Grade 3 or 4 [8]. Age increases the incidence of cases with CLD grade 1 and decreases in those with grades 2 or 3. Therefore, as the child ages, the view in direct laryngoscopy improves, and intubation becomes generally easier. It is explained by the gradual reduction of anatomical differences in pediatric and adult airways, as they diminish after the age of 2 [8].

However, some causes of difficult laryngoscopy do not disappear with age because it is more common in children with congenital syndromes that often share a common feature of micrognathia. This abnormality causes difficulties in the laryngoscopic visualization of the glottis [8].

Difficult laryngoscopy might require more effort or requesting another person's help. Yet multiple tracheal intubations and direct laryngoscopy attempts were associated with more complications. More than two intubation attempts were linked to a high failure rate [4]. While the more intubation attempts are made, the worse the outcomes are; it seems crucial to be able to assess the difficulty beforehand. Unfortunately, Cormack and Lehane's grades can only be assessed during direct laryngoscopy. Therefore, it is not known in patients being prepared for

| Grade | Description | Image |
|---|---|---|
| Grade I | Full exposure of glottis (anterior and posterior commissure) |  |
| Grade II | Anterior commissure not visualized |  |
| Grade III | Epiglottis only |  |
| Grade IV | No glottic structure visible |  |

**FIGURE 1.** Cormack-Lehane grading scale

their first procedure. Nevertheless, the assessment is partially possible thanks to bedside tests — parameters measured in the anesthesia clinic during qualification visits.

## Bedside tests and measurements

### *Mallampati test (MMC) and Best Oropharyngeal View (BOV)*

Mallampati first developed the Mallampati classification, which was later modified by Samson in 1987. The test is performed in patients sitting straight up who are asked to open their mouths and protrude their tongues out maximally. The result of the Modified Mallampati Classification (MMC) is marked as Classes I to IV, depending on the visible structures of the oropharynx [13]. The Mallampati classification system is presented in Figure 2.

The Mallampati test was found to be the most accurate assessment to predict difficult laryngoscopy in school-age children (over five years old) [14, 15]. Similar results were reported in one large study of over 11 000 patients, where Mallampati Classes III and IV correlated with Cormack Lehane Grade III and IV findings. However, the authors stated that the Mallampati test often could not be assessed due to the patient's young age and lack of cooperation. Hence, the proportion of documented Mallampati results decreased in the younger age groups and could influence the results [12]. Overall, in patients from all pediatric age groups, the Mallampati test might show reduced accuracy in predicting a poor view of the glottis during direct laryngoscopy [8]. In addition, it was suggested that children under three years old are not cooperative enough to allow MMC assessment, and its results do not correlate with clinical outcomes. Therefore, Mallampati Modified Classification cannot sufficiently predict difficult laryngoscopy and intubation for all pediatric patients [8].

Aggarval et al. [8] proposed an alternative method, as the majority of their study group (1–5 years old) was too young to perform the classic Mallampati test. Their method was called Best Oropharyngeal View (BOV) and is similar to the MMC assessment — the mouth should be wide open, but this test skips the tongue protrusion. With the classic MMC test, authors managed to assess only 82% of the group, whereas the BOV assessment was successful in 96% of their patients. In addition, there was a statistically significant correlation between BOV and Cormack and Lehane Grade (CLG) and intubation difficulty score, and this new parameter was announced as a better pediatric airway assessment

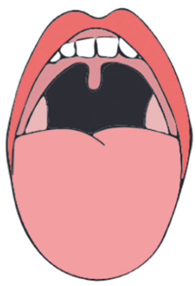
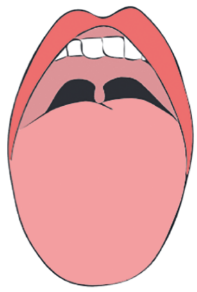
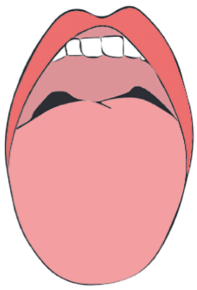
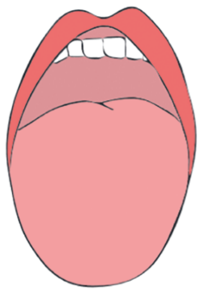
| Class | Description | Image |
|---|---|---|
| Class I | Complete visualization of the soft palate |  |
| Class II | Complete visualization of the uvula |  |
| Class III | Visualization of only the base of the uvula |  |
| Class IV | Soft palate in not visible at all |  |

**FIGURE 2.** The Mallampati classification system

tool than MMC. However, further studies are necessary to validate the new test's use.

## *Thyromental distance (TMD) and ratio height to TMD (RHTMD)*

Thyromental distance (TMD) is a very simple test measured when the patient fully extends the neck with the mouth closed. It is defined as the distance between the chin and the top of the thyroid notch and is used to estimate the size of the mandible floor. In adults, TMD of < 6 cm indicated the increasing difficulty of direct laryngoscopy, but in another research, its role was rather unclear. The interobserver variability may be high, and especially in children, discrete values might be difficult to classify [1, 8]. One research did not find TMD value to correlate with easy or difficult airway groups. However, the study population comprised only 48 pediatric patients [16]. Many other research papers in children confirmed that as the TMD increased, intubation difficulty [8, 17] and Cormack and Lehane Grade [8, 15, 18, 19] decreased. TMD had the highest specificity (99.11%), positive predictive value (93.8%), and accuracy (95.2%) of multiple bedside tests that were assessed by Inal et al. [20]. In the PeDI study, increased TMD was independently associated with the occurrence of any complication [4]. TMD cut-off points proposed for children varied between studies and were estimated for 5 cm [14], 5.5 cm [20], and 6.3 cm [15].

It was also suggested to compare TMD to height in centimeters and create another parameter: ratio height to TMD (RHTMD). The conclusions are inconsistent – one research suggests a significant correlation between RHTMD value and Cormack Lehane Grade [15], and another denies it but then finds relationships with intubation difficulty scored by practitioners [8]. Proposed cut-off points for children were estimated at 18 cm, 21.5 cm, and 23.5 cm, but RHTMD had the lowest positive predictive value, low sensitivity, and low specificity. Therefore it was ranked a poor predictor of difficult laryngoscopy compared with other parameters [14, 15, 20].

## Sternomental distance

Sternomental distance (SMD) is assessed in the same position as TMD but is measured between the chin and the upper border of the sternal notch. It helps examine the patient's ability to extend the neck — in adults, an SMD of < 12 cm suggests a decreased degree of neck extension [1]. Some authors find significant correlations between SMD in children and Cormack Lehane Grade III or IV [18] and intubation difficulty [8]; other authors do not prove similar links [8, 16]. However, relatively little research assessed SMD's usefulness compared to other parameters, and their results are inconclusive, so further studies on that topic are much needed.

## Upper lip biting test (ULBT)

Upper lip biting test (ULBT) is one of the mandibular protrusion tests used to assess the functionality of the temporomandibular joint. The patient is asked to bite their upper lip with their lower teeth, which estimates the ease of anteriorly lifting the mandible by simulating a movement similar to the one performed during laryngoscopy. ULBT's results depend on mandibular mobility and teeth structure. If the patient cannot perform the test, the temporomandibular joint's mobility is considered decreased, which suggests difficult direct laryngoscopy [1]. The result is grouped into three classes depending on the range of motion. Although many studies in adults prefer ULBT for its simplicity and show it to be more predictive than MMC or TMD, in pediatric patients, its use might be reduced because of the lack of cooperativeness. In one study, 80% of children who could not perform ULBT were under six years old, proving a significant limitation for the applicability of this test in younger groups [16]. Even in cases where ULBT is assessed, its usefulness is very unclear — its sensitivity ranged from 58.33% to 83%, specificity from 79.55% to 97.32%, accuracy from 77% to 94.4%, and positive prognostic value from 45.7% to 75% [14–16, 20].

## Mouth opening and interincisor distance

Mouth opening is measured as the distance between incisors when the mouth is maximally opened. It should be evaluated in centimeters (and be ≥ 4 cm) or, in practice, as fingerbreadths (at least 3). It can be one of the most relevant tests for selecting an intubation technique and airway management tool [1]. In pediatric studies, interincisor distance (ID) correlated with Cormack and Lehane Grade [18] and differed significantly between the easy and challenging intubation group but had the lowest area under the curve of all assessed parameters. The authors calculated the cut-off value to 2.6 cm [16]. It should be taken into account that the inter-incisor distance is prone to essential changes because of the deciduous teeth development, shedding, and replacement with permanent teeth.

## Distance from frontal plane to chin

Distance from frontal plane to chin (DFC or FPTC) is the shortest distance in centimeters between the chin and the bridge of the nose measured from the lateral view. It is used to assess retrognathia. DFC correlates with laryngoscopic difficulty — in one study, it was shown to be the best predictor for patients aged from 4 to 12 years. It was also suggested to divide this parameter by weight — in the youngest group (0–6 months), this DFC/weight ratio higher than 0.2 had 88.89% and 73.68% of specificity. Therefore, retrognathism might be an essential and reliable risk factor for laryngoscopic difficulty in very young patients [16, 18].

## Anthropometric measurements

As all bedside tests mentioned above require some form of action from the patient (neck extension, mouth opening, etc.), a few other techniques to be measured at rest were also proposed. These anthropometric measurements may be helpful for non-cooperating children, but data is often limited to a single study.

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Hyomental distance (HMD) is the distance between the mentum (tip of the chin) and the hyoid bone and is used to estimate the mandibular space. In adults, it can be more sensitive in predicting difficult intubation than TMD, especially when measured with ultrasonography [21]. One study in children showed that HMD correlated with easy and difficult intubation groups [16].

Three proposed measurements depend on the ear position. Two of them (ear lobe or ear tragus to the corner of the mouth) significantly differed between easy and difficult intubation. Distance from the ear tragus to the corner of the mouth was directly associated with the difficult laryngoscopy. By contrast, parameters including an ear lobe had an inverse association [x]. Only in children younger than five years old, decreasing distance between ear tragus and nares (tn) correlated with increasing Cormack and Lehane Grades. According to the authors, this measurement can surrogate for mandibular length and larynx position: the shorter the Tn, the more anterior the larynx and more difficult intubation should be expected [19].

Position of the mouth understood as the distance from the lower border of the nose to the upper lip border and the lower lip border to the mentum, showed no link to easy or difficult intubation group. However, the second parameter had a direct association with difficult laryngoscopy.

In 2011 Mirghassemi et al. [17] proposed the following equation to predict laryngoscopic difficulty: $Y = (0.015 \times L) + (0.007 \times T) - (0.015 \times E) + 0.179$, where L is the distance from the lower lip border to the mentum, T is the distance from ear tragus to the corner of the mouth, and E is the distance from ear lobe to the corner of the mouth. Using the multivariate regression analysis, the authors found that the probability of difficult laryngoscopy is greater if the Y tends toward 1.

### COPURway Score

When difficult intubation is anticipated, it is helpful to rate the degree of difficulty. This allows planning primary and alternative airway management strategies, engaging experienced professionals, and ensuring the presence of required equipment. One of the systems to assess the degree of difficulty is the Colorado Pediatric Airway Score (COPURway Score — Tab. 1 and 2) which links the focus on history taking, bedside tests, and other measurements.

This anagram is used to describe five evaluated characteristics: C (chin size), O (opening — interdental distance between front teeth), P (previous intubation or obstructive sleep apnea), U (uvula visualization), and R (estimated range of motion of neck), each rated on a 4-point scale. The COPURway Score can predict glottic views in the Cormack and Lehane Classification. Scores above 12 predict difficult intubation (CL grade 3 and 4) and are grouped into suggested airway management care levels that include recommendations like fiberoptic or awake intubation [8, 11, 17]. Inventing scores similar to this one, which combines many types of risk factors discussed in this paper (including incidents of previous difficult airways, anthropometric measurements, and mobility tests), can be an element of a multimodal approach and a holistic view of the pediatric patient being assessed for intubation difficulty.

**Table 1. Colorado Pediatric Airway Score (COPUR)**

| Colorado Pediatric Airway Score (COPUR) | Points |
|---|---|
| **C: chin** | |
| From the side view, is the chin: | |
| • Normal size? | 1 |
| • Small, moderately hypoplastic? | 2 |
| • Markedly recessive? | 3 |
| • Extremely hypoplastic? | 4 |
| **O: opening** | |
| *Interdental distance between the front teeth:* | |
| • 40 mm | 1 |
| • 20–40 mm | 2 |
| • 10–20 mm | 3 |
| • < 10 mm | 4 |
| **P: previous intubations, OSA (obstructive sleep apnoea)** | |
| • Previous intubations without difficulty | 1 |
| • No past intubations, no evidence of OSA | 2 |
| • Previous difficult intubations, or symptoms of OSA | 3 |
| • Difficult intubation — extreme or unsuccessful; emergency tracheotomy; unable to sleep supine | 4 |
| **U: uvula** | |
| *Mouth open, tongue out, observe palate* | |
| • Tip of uvula visible | 1 |
| • Uvula partially visible | 2 |
| • Uvula concealed, soft palate visible | 3 |
| • Soft palate not visible at all | 4 |
| **R: range** | |
| *Observe line from ear to orbit, estimate range of movement, looking up and down* | |
| • > 120° | 1 |
| • 60°–120° | 2 |
| • 30°–60° | 3 |
| • < 30° | 4 |
| Modifiers: add point for | |
| • Prominent front 'buck' teeth | 1 |
| • Very large tongue, macroglossia | 1 |
| • Extreme obesity | 1 |
| • Mucopolysaccharidoses | 2 |

## CONCLUSIONS

Difficult airways in children can be anticipated or unanticipated, with most difficult airways being predictable. These airways may result from congenital syndromes, anatomical airway dysfunctions, or pre-existing respiratory risk factorsA detailed clinical exam should evaluate the symmetry of the head, face, and neck, oral pathologies, oral hygiene, and neck movements. Children with congenital syndromes may have an impact on airway management, with features like limited neck length or mobility, micrognathia, tongue retraction, and mandibular hypoplasia. Multiple dysmorphic features may coexist in the same patient, and some abnormalities affecting airway management may not be easily visible.

Perioperative assessment should include observing the face from both the front and the side, as well as visualizing the child from the lateral profile. Taking an airway-focused history helps identify respiratory

Table 2. Colorado Pediatric Airway Score (COPUR)

| Prediction points | Intubation difficulty | Glottic view |
|---|---|---|
| 5–7 | Easy, normal intubations | 1 |
| 8–10 | More difficult, laryngeal pressure may help | 2 |
| 12 | Difficult intubation, fibreoptic less traumatic | 3 |
| 14 | Difficult intubation, requires fibreoptic or other advanced methods | 3 |
| 16 | Dangerous airway, consider awake intubation, advanced methods, potential tracheotomy (Patients with hypercarbia awake, severe obstruction) | 4 |
| 16+ | Scores > 16 are usually incompatible with life without an artificial airway | |

issues during previous admissions. Reviewing medical documentation and including information about difficulties encountered during airway management is essential for further care.

In light of these conclusions, it is evident that standardized and reliable pediatric airway assessment scales are crucial for accurately evaluating and managing difficult airways in children. By implementing structured airway assessment protocols, healthcare providers can better understand and address the challenges and risk factors specific to pediatric patients, thereby improving the safety and success of airway management. Furthermore, continued research and the development of specialized assessment tools tailored to the pediatric population are necessary to further enhance patient outcomes and minimize complications.

## Article information and declarations

### Author contributions

Conceptualization — K.M.; methodology — N.B.; validation — L.S. and S.B.; formal analysis — L.S.; writing — original draft preparation — K.M.; writing-review and editing — N.B., S.B. and A.O.; supervision — L.S. All authors have read and agreed to the published version of the manuscript.

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### Conflict of interest

None declared.

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