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Pediatric Anesthesia

RESEARCH REPORT OPEN ACCESS

Availability and Practice Patterns of Videolaryngoscopy and Adaptation of Apneic Oxygenation in Pediatric Anesthesia: A Cross-Sectional Survey of Pediatric Anesthesiologists

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Received: 22 June 2024 | **Revised:** 17 January 2025 | **Accepted:** 27 January 2025

Funding: The study was solely supported by departmental sources.

Keywords: apneic oxygenation | difficult tracheal intubation | pediatric anesthesia | survey | videolaryngoscopy

ABSTRACT

Background: Videolaryngoscopy (VL) and apneic oxygenation are highly recommended and increasingly used in pediatric anesthesia practice; yet, availability, use in recommended clinical settings (e.g., neonates, airway emergencies, and out-of-operating-room tracheal intubation), and the association of VL availability with how pediatric anesthesiologists define difficult intubation have not been explored.

Method: An electronic survey was distributed to the members of several international pediatric anesthesia societies to examine the availability and practice patterns of VL and to explore the criteria used to define a difficult tracheal intubation in children in the context of VL.

Results: The response rate was 12.9%. VL was reported to be "most likely available" in main pediatric operating rooms and off-site locations 93% and 80.1% of the time, respectively. Fifty-seven percent of participants would select VL first when anticipating a difficult tracheal intubation; nearly 30% of respondents would choose direct laryngoscopy first and VL as a backup in this scenario. One-third of subjects would select VL as their first choice for nonoperating room (non-OR) emergency tracheal intubation and for premature or newborn infants, regardless of anticipated difficulty with intubation. Thirty percent of subjects reported using apneic oxygenation during difficult laryngoscopy. Institutional VL availability was not associated with how providers defined difficult tracheal intubation.

Conclusion: VL is highly available, but the adoption of VL and apneic oxygenation for managing difficult tracheal intubation was lower than expected, given recent recommendations by pediatric anesthesia societies. There was heterogeneity in how difficult intubation was defined, resulting in a possible patient safety risk.

1 | Introduction

While conventional direct laryngoscopy (DL) remains the mainstay in pediatric anesthesia, videolaryngoscopy (VL) is increasingly used in children because of better glottic visualization, higher first-attempt success, and fewer airway-related complications [1–6]. Because of these benefits, VL has been recommended by several pediatric anesthesiology societies as the first choice for tracheal intubation in expected difficult airway scenarios, in children with limited cardiopulmonary reserve, such as neonates, and in nonoperating room (non-OR) emergency settings [7–9]. However, concerns persist regarding VL's

availability and the impact on training and maintenance of DL skills, making its use as the standard of care in tracheal intubation controversial in pediatric anesthesiology [10–12].

The adoption of VL in adult anesthesia practice has changed how anesthesiologists define a "difficult" tracheal intubation. A recent survey showed substantial variability in how anesthesia providers defined a "difficult" intubation and the threshold for activating a difficult airway alert, depending on VL availability [13]. While two-thirds of anesthesiologists surveyed considered three or more intubation attempts as difficult, only 10.9% considered the traditional Cormack–Lehane (C/L) grade 3–4 views with DL difficult, which are classic definitions of a difficult airway. The use of VL was associated with greater discrepancies between documentation and the definitions of difficult tracheal intubation recommended by ASA guidelines [13, 14]. Despite increased recommendations for VL use in various pediatric patients, it is unclear whether the use and availability of VL are associated with increased variability in the criteria pediatric anesthesiologists use to define a difficult tracheal intubation.

Additionally, recent evidence supports the use of apneic oxygenation during difficult tracheal intubation, as it prolongs safe apnea time and improves first-attempt intubation success [4, 15–19]. This has led to recommendations for its use from several pediatric anesthesia societies to reduce adverse events in anticipated difficult intubation scenarios [8, 16, 20]. However, it is unknown to what extent this technique has been integrated into pediatric anesthesia practice.

Therefore, the primary objectives of this study were to describe the availability of VL and its use in pediatric anesthesia practice and to explore the criteria used to define a difficult tracheal intubation in relation to VL availability by pediatric anesthesiologists. Additionally, the survey was designed to evaluate the adoption of apneic oxygenation among pediatric anesthesiologists during difficult intubation. Our secondary objective was to assess the relationship between the background characteristics of survey participants and their practice patterns of VL in pediatric anesthesia.

2 | Materials and Methods

This cross-sectional multi-society survey was reviewed by the University of Michigan Institutional Review Board, and the requirement for informed consent was waived (HUM00226446). The article followed the Checklist for Reporting of Survey Studies [21].

2.1 | Survey Development

The authors developed the questionnaire and pilot-tested it with 30 pediatric anesthesia practitioners from the Department of Anesthesiology, University of Michigan. The questionnaire was reviewed by a survey specialist at the University of Michigan, the Pediatric Difficult Intubation (PeDI) Registry Group, Society for Pediatric Anesthesia (SPA), and the Scientific Committee of the Association of Paediatric Anaesthetists of Great Britain and Ireland (APAGBI). On the basis of feedback, specific video laryngoscope blades (e.g., standard and nonstandard) were incorporated. Additional edits included the addition of "consultant anesthetist" as a job description and the adoption of "pediatric hospital with trainees" as a workplace location, enhancing inclusivity for non-SPA members. The survey was administered using Qualtrics (Provo, UT), a web-based survey platform.

2.2 | Questionnaire (Including Primary Outcomes and Exposure Variables)

The questionnaire (Data S1) contained 21 questions to (1) describe VL's availability in pediatric ORs and non-OR anesthetic locations, (2) access pediatric anesthesia practitioners' adherence to clinical guidelines for using VL and apneic oxygenation in children ≤ 12 years old in various settings, and (3) examine how difficult tracheal intubation is defined in the context of VL availability by pediatric anesthesiologists. Data on respondent characteristics included pediatric anesthesiology fellowship training, years in practice, hospital setting (pediatric or mixed adult/pediatric), the percentage of pediatric patients, presence of trainees, the number of difficult intubations encountered in the last year, and membership in international pediatric anesthesia societies.

2.3 | Survey Distribution

The survey was approved and distributed by the SPA to all members via email. Internationally, we obtained approval to distribute the survey to members from APAGBI, the Canadian Paediatric Anesthesia Society (CPAS), the European Society for Paediatric Anaesthesiology (ESPA), the Indian Association of Paediatric Anaesthesiologists (IAPA), and Paediatric Anaesthesia in New Zealand and Australia (SPANZA) via email or newsletters containing the survey link.

The survey was anonymous and open from August to November 2023, with 1–2 reminders sent to complete it. The data were hosted on Qualtrics, University of Michigan. Using Qualtrics features like IP address and Response ID tracking, we were able to identify and eliminate duplicate responses.

2.4 | Statistical Analysis

To describe the perceived availability and practice patterns of VL among pediatric anesthesiologists and examine the criteria for defining difficult tracheal intubation, we used descriptive statistics such as frequencies, proportions, and bar plots. As no more than 5% of data was missing for any question, a complete case analysis was performed.

Next, given the study's descriptive nature and non-random sample, basic descriptive statistics, along with unadjusted comparisons from cross-tabulation and permutation-based testing, are used to identify potential measures that could explain differences in our primary outcomes. We measured unadjusted associations between our primary outcome variables and participant characteristics and practice settings using chi-squared tests. Specifically, we assessed associations with years in practice

(dichotomized at < 10 vs. ≥ 10 years after training), practicing ≥ 50% vs. < 50% pediatric anesthesia, and the perceived availability of VL at the participant's hospital. We categorized VL availability on the basis of its availability in non-OR locations (such as radiology or cardiac catheterization) because availability there is often more limited and it therefore may be a more sensitive indicator of overall VL availability, especially when the number of video laryngoscopes is low. We defined low VL availability as a perception of VL being available < 75% of the time in non-OR anesthetic locations. Upon the editor's suggestion and using the recommended software, we learned that our sample size was sufficient for making inferences at a 95% confidence level. This ensures that the true value is within ± 5% of the measured value for the surveyed societies, though not necessarily for the broader pediatric anesthesia population.

3 | Results

A total of 900 of 6954 invited members completed the survey, with no duplicate responses found, resulting in an overall response rate of 12.9%. Among these, the 868 subjects who cared for children ≤ 12 years were included in our analysis. Most respondents were anesthesiologists with pediatric anesthesia subspecialty training who worked with trainees either in a pediatric (50.4%) or in a mixed adults and children (40.4%) hospital. More than 70% of respondents practiced mainly pediatric anesthesia (≥ 50% pediatric anesthesia practice); 58.7% had ≥ 10 years' experience after training including 30% with ≥ 20 years' experience. 55.2% of the respondents reported 1–4 difficult tracheal intubations in the last year, and a quarter had 5–9 per year. Members from SPA and APAGBI comprised 43% and 23% of respondents, respectively. See Table 1 for participants' characteristics.

3.1 | Availability of VL

Overall, 93% (744/833) of respondents indicated that VL was "most likely available" in the main pediatric ORs; 80.1% (644/829) indicated VL was available in non-OR locations, consistently reported across most societies. IAPA members reported VL availability in main ORs and non-OR locations as 70.6% and 21.6%, respectively, although their response rate was low (51/1045). We avoided comparing the practice patterns between each society because of small respondent numbers that could introduce bias. Nevertheless, it remains worthwhile to examine practice patterns. See Figure 1 for VL availability across the six represented pediatric anesthesia societies.

4 | Notable Practice Patterns of VL in Pediatric Anesthesia

4.1 | When Anticipating Difficult Tracheal Intubation

Overall, 56.5% (402/711) of participants reported they would most likely select VL first when anticipating difficult tracheal intubation; 33% responded that they always chose VL in this situation. Nearly 30% of responders selected DL as the first choice and VL as the backup in this scenario. Participants with high VL availability selected DL as the first choice in 26% (149/574) compared with 39.4% (52/132) of respondents with low VL availability ($p = 0.002$). Similarly, 24.9% (72/289) of anesthesiologists with < 10 years of practice chose DL as the first option in this scenario compared with 30.9% (129/ 418) with ≥ 10 years of practice; however, this association was not statistically significant ($p = 0.09$).

4.2 | VL as the First Choice in Neonates

Twenty-nine percent of participants (205/704) reported that they would very likely choose VL as the first choice for tracheal intubation in premature and newborn infants regardless of perceived difficulty with intubation. Sixteen percent reported they would choose VL in infants ages 1 month to < 1 year old, and < 10% reported they would likely select VL as their first choice in children 1- to 3-year-olds. Compared with subjects with < 10 years of post-training experience, participants with ≥ 10 years of practice were less likely to choose VL as the first choice in neonates (26.4% vs. 33.1%, $p = 0.05$). Subjects working in institutions with low perceived VL availability were also less likely to choose VL as the first-line intubation device in premature infants and neonates (17.8% vs. 31.7%, $p = 0.002$).

4.3 | VL as the Standard of Care in Neonates and Children

Forty percent (345/868) of subjects agreed VL should be the standard first-line technique for tracheal intubation in premature and newborn infants. Among participants with ≥ 10 years of practice, 36.9% agreed with the above statement compared with 45.5% of anesthesiologists who were in practice < 10 years ($p = 0.013$). In addition, 28% (240/868) agreed it should be the first-line technique in infants ages 1-month to 1-year old. Thirty-three (291/868) of participants felt that VL should never be the standard of care for the first attempt at tracheal intubation in all children. The participants with low VL availability compared with high VL availability (26.1% vs. 37.2%, $p = 0.007$), those with < 10 years of practice after training compared with ≥ 10 years of practice (28.9% vs. 37.7%, $p = 0.008$), and those whose practice was ≥ 50% pediatrics compared with < 50% (26.6% vs. 36.9%, $p = 0.006$) were significantly less likely to agree with that statement.

4.4 | VL as the First Choice in Non-OR Emergency Tracheal Intubation

Thirty-three percent of subjects (230/704) reported they were likely to use VL as the first choice for non-OR emergency tracheal intubation. The practice pattern was significantly less likely among participants with ≥ 10 years of practice after training compared with participants with < 10 years of practice (27.9% vs. 39.6%, $p = 0.001$) and among those with low VL availability compared with high VL availability (18.6% vs. 35.9%, $p < 0.001$).

See Figure 2 for practice patterns of VL in pediatric anesthesia. See Table S1 for cross tabulation of survey participants' background characteristics and practice patterns of VL.

TABLE 1 | Participants' background characteristics.

Background characteristics		*N* (*n* = 868)	%
Role in anesthesia care team (missing = 13)	Anesthesiologist with pediatric anesthesia specialty training	756	88.42
	Other nonphysician anesthesia provider	24	2.81
	Anesthesiologist without pediatric anesthesia specialty training	42	4.91
	Pediatric anesthesia fellow/resident	26	3.04
	Others	7	0.82
Years of practice after training (missing = 15)	In training	15	1.76
	< 5	165	19.34
	5–9	172	20.16
	10–19	245	28.72
	> = 20	256	30.01
Hospital settings	Adult and children with anesthesia trainees	351	40.44
	Adult and children without anesthesia trainees	61	7.03
	Pediatric hospital with anesthesia trainees	437	50.35
	Pediatric hospital without anesthesia trainees	42	4.84
	Outpatient surgical center	52	5.99
	Others	58	6.68
Percentage of pediatric anesthesia practice (missing = 18)	< 25%	98	11.53
	25%–50%	120	14.12
	50%–75%	80	9.41
	> 75%	552	64.94
Difficult tracheal intubation encountered in the last year (missing = 171)	0	44	6.31
	1–4	385	55.24
	5–9	169	24.25
	> = 10	99	14.20
International pediatric anesthesia society	APAGBI (1000 members)	196	23
	CPAS (294 members)	62	7
	ESPA (684 members)	43	5
	IAPA (1045 members)	51	6
	SPA (3500 members)	371	43
	SPANZA (460 members)	19	2
	Others	38	4

Abbreviations: APAGBI, Society for the Association of Paediatric Anaesthetists of Great Britain and Ireland; CPAS, Canadian Paediatric Anesthesia Society; ESPA, European Society for Paediatric Anaesthesiology; IAPA, Indian Association of Paediatric Anaesthesiologists; SPA, Society for Pediatric Anesthesia; SPANZA, Paediatric Anaesthesia in New Zealand and Australia.

4.5 | Criteria to Define a Difficult Tracheal Intubation

More than half the participants agreed with traditional criteria used to define a difficult tracheal intubation, including three or more intubation attempts (513/868, 59.1%), C/L grade 3–4 view by DL (483/868, 55.7%), C/L grade 3–4 view gained by VL with a standard (490/868, 56.5%) or nonstandard blade (496/868, 57.1%), and a history of difficult intubation (472/868, 54.4%). Eighteen percent (155/868) of participants agreed that a C/L grade 2B view on VL with a standard blade should be classified as difficult; 31% (269/868) agreed that a C/L grade

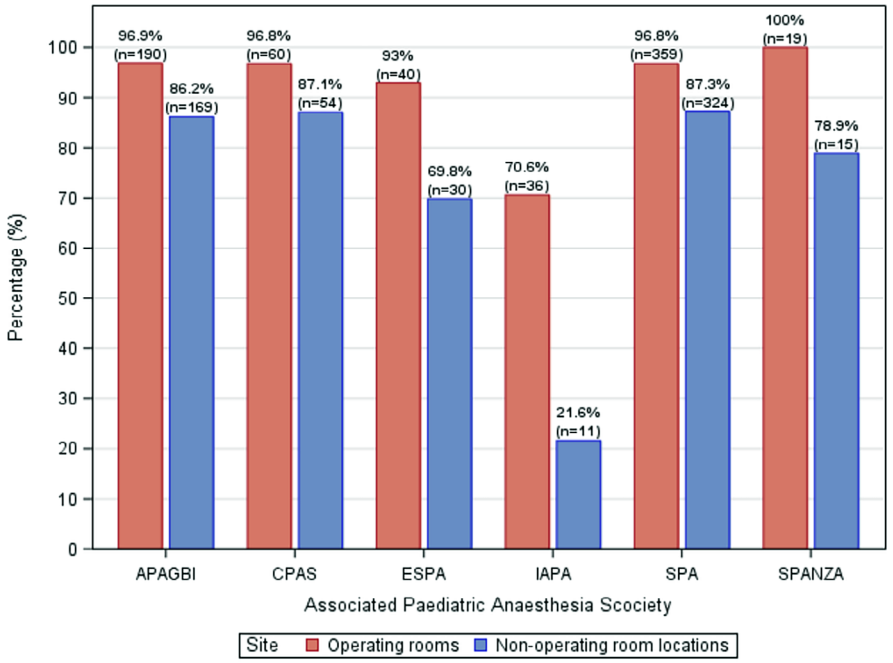

FIGURE 1 | Availability of videolaryngoscopy (VL) in pediatric operating rooms and nonoperating room anesthetic locations by international pediatric anesthesia societies (n = participants responded VL being most likely available). International pediatric anesthesia societies and number of respondents were as follows: APAGBI, Society for Association of Paediatric Anaesthetists of Great Britain and Ireland 196; CPAS, Canadian Paediatric Anesthesia Society 62; ESPA, European Society for Paediatric Anaesthesiology 43; IAPA, Indian Association of Paediatric Anaesthesiologists 51; SPA, Society for Pediatric Anesthesia 371; SPANZA, Paediatric Anaesthesia in New Zealand and Australia 19.

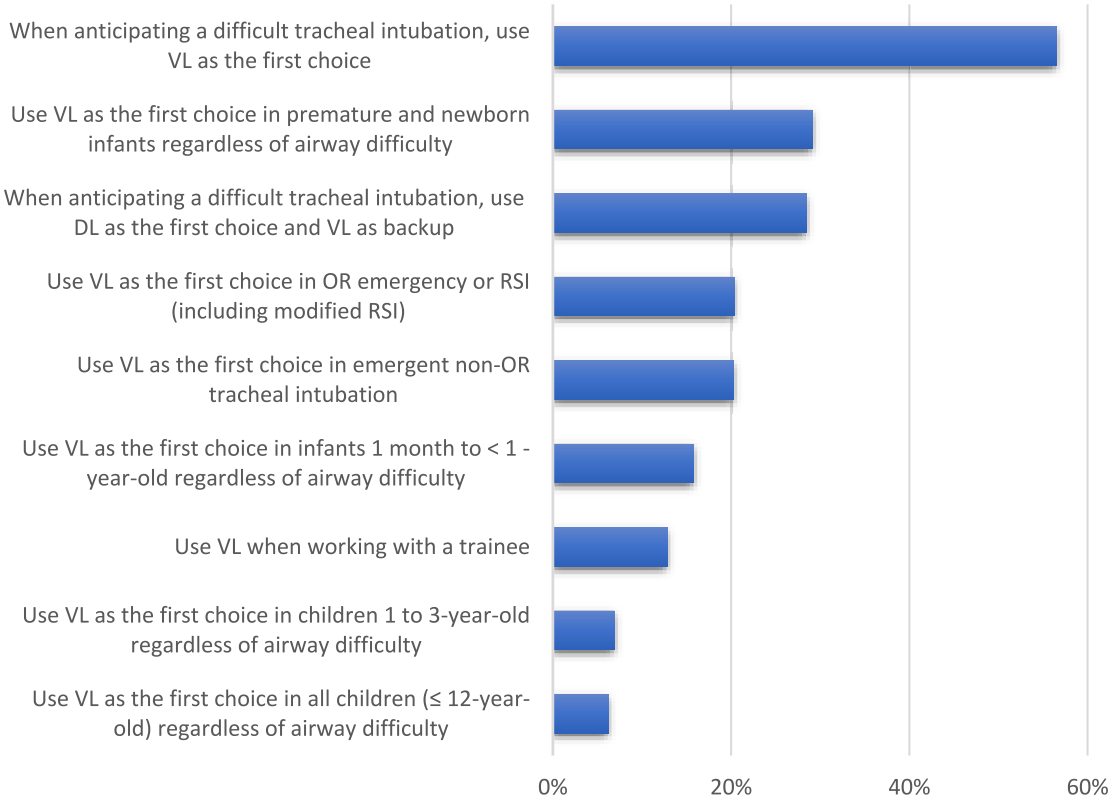

FIGURE 2 | Practice patterns of videolaryngoscopy in pediatric anesthesia. DL, direct laryngoscopy; RSI, rapid sequence induction; VL, videolaryngoscopy.

2B view on VL with a nonstandard blade was difficult. Comparing anesthesiologists working in institutions with high versus low VL availability, similar proportions regarded a C/L grade 3–4 view by DL as a difficult intubation criterion (59.3% vs. 53.3%).

Few participants considered C/L grade 1–2A view on VL as difficult either with a standard blade (24/868, 2.8%) or with a nonstandard blade (67/868, 7.7%). See Figure 3 for criteria used by participants to define a difficult intubation in the context of VL.

4.6 | Using Apneic Oxygenation During Difficult Tracheal Intubation

Thirty percent (212/699) of participants reported they were likely to use apneic oxygenation during difficult tracheal intubation; 28.1% (197/699) reported they never used this technique. The use of apneic oxygenation was not associated with participant background variables.

5 | Discussion

This is the first cross-sectional survey describing current availability and clinical practice patterns of VL and apneic oxygenation for pediatric intubation in North America, Europe, Asia Pacific, and South Asia. VL was reported to be highly available in both pediatric ORs and non-OR anesthetic locations, representing significant increases since 2017 when a study from the United Kingdom reported 22% availability of VL in pediatric anesthesia practice [22]. This is most likely attributable to the development of video laryngoscopes tailored to children over the last decade and increased evidence of improved intubation outcomes in certain populations with its use [1–4]. However, not all anesthesia providers have equal access to these devices. Members from IAPA reported much lower VL availability than members from other pediatric anesthesia societies. This disparity is likely related to factors contributing to global inaccessibility of basic surgical services, a significant global public health problem [23].

Second, despite evidence that DL has a low first-attempt success rate compared with VL in the management of anticipated difficult airway [1–6] and that multiple attempts increase intubation-related adverse events [24, 25] we found that nearly 30% of the respondents chose DL for the first attempt and VL for backup in this scenario. Similarly, only one in three participants used VL as the first choice in children requiring emergency intubation in non-OR settings. Given the overall high availability of VL, the authors believe that VL is often underutilized when managing an anticipated pediatric difficult intubation. Preferred use of DL in these scenarios was associated with lower VL availability. Thus, improvement of VL availability in resource-limited regions may boost VL's utilization in this clinical situation.

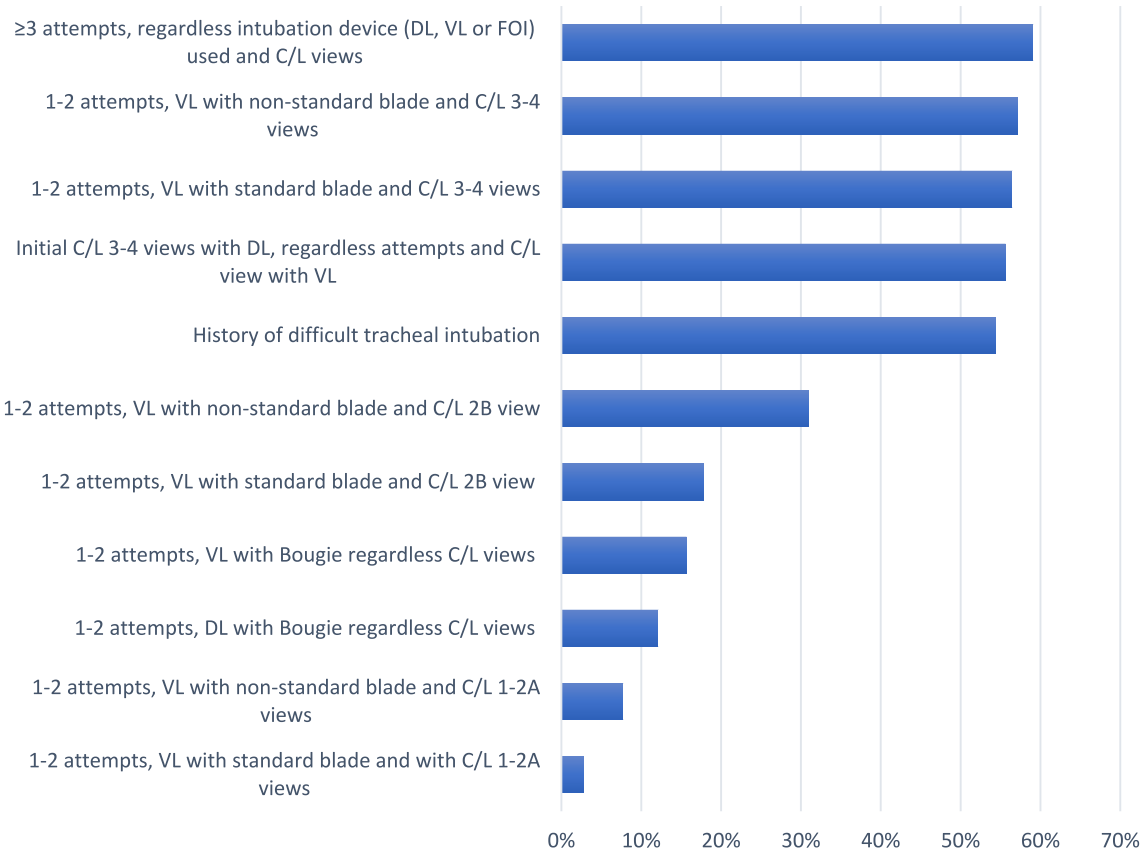

FIGURE 3 | Criteria used by participants to define a difficult intubation in the context of videolaryngoscopy. DL, direct laryngoscopy; FOI, fiberoptic intubation; VL, videolaryngoscopy. C/L, Cormac–Lehane (Classification: Grade1, full view of the glottis; grade 2A, partial view of the glottis; grade 2B, arytenoids or very posterior origin of the cords; grade 3, only the epiglottis is visible; and grade 4, no glottis structure visible).

Third, our survey found that a minority of participants selected VL as the first tracheal intubation technique in neonates and infants despite recent studies demonstrating the superiority of using VL with a standard blade for first-attempt success with reduced complications [3, 4] and practice guidelines strongly recommending VL as the initial intubation device in neonates and infants [8]. Infants, and especially neonates, present physiologic challenges during airway management because of higher oxygen consumption, lower functional residual capacity (FRC), and higher closing capacity, and are at increased risk of significant oxygen desaturation [3, 25]. These features often limit the time for each intubation attempt and may lead to complications if there are multiple intubation attempts [24, 25]. Furthermore, unexpected difficult tracheal intubation may occur more frequently in neonates and infants than in older children [25]. Participants with low VL availability or with ≥10 years of practice after training were less likely to use VL as the initial technique in these clinical situations. Failure to use VL first in this population represents a missed opportunity to improve patient safety.

We considered several reasons for the low uptake of VL among respondents, even when a difficult airway is expected, and despite high availability. These included the following: (1) Training and familiarity: Pediatric VL has been expanding in pediatric anesthesia for a decade. However, many pediatric anesthesiologists who completed this survey have practiced for over 10 years (58.73% of participants). This group may not have received extensive VL training, may feel most comfortable with DL, or may be resistant to changing established practice. (2) Perceived complexity using VL: Some practitioners have difficulty inserting the endotracheal tube (ETT) through the glottic opening despite easy visualization with VL or may see VL as more cumbersome and time-consuming to use than DL. (3) Cost and accessibility: Video laryngoscope price and maintenance can be high. (4) Delays in creating institutional policies for addressing difficult airways because of cost or availability. Additional studies should explore the reasons for failing to adopt recommended practices in this subset of children.

Fourth, like adult studies [13, 14], we found substantial variability in the criteria used by anesthesiologists to define a difficult tracheal intubation. Even for commonly used criteria (e.g., three or more attempts, C/L view 3–4 gained by DL or VL, and history of difficult intubation), only half of the participants agreed these scenarios constituted difficult intubation. Unlike in the adult study [13], we did not find that the availability of VL had a significant impact on whether respondents defined a grade 3–4 C/L view gained by DL as difficult or not difficult. This may be related to the higher usage of VL as the first intubation instrument (56.5%) when anticipating a difficult tracheal intubation in our study than in the adult study. One-third of the participants defined a 2B view with a nonstandard VL blade as difficult, whereas only 18% considered a 2B view with a standard VL blade difficult. These inconsistencies in criteria used by anesthesiologists to define a difficult tracheal intubation when using VL may represent a hidden threat to patient safety as inconsistent documentation of difficult airway across providers may result. The associated risks may be mitigated by the delineation of specific criteria for difficult tracheal intubation designation and alert activation at the institutional level [13].

Finally, despite multiple studies showing increased first-pass intubation success rate and decreased risk of oxygen desaturation and society guidelines recommending its use [4, 8, 15, 17–19], respondents were unlikely to use apneic oxygenation during difficult laryngoscopy. Future work should investigate whether this is related to a lack of appropriate equipment, a lack of knowledge about its effectiveness, or resistance to changing existing practice.

The following key gaps were identified in this survey. (1) Resource disparities: There appear to be significant gaps in the availability of video laryngoscopes across various healthcare settings. This is particularly true for members from IAPA, where access to advanced equipment might be limited. (2) Underutilization of VL among pediatric anesthesiologists for scenarios such as the known difficult airway, the neonatal airway, and during emergency intubations outside of the OR despite recommendations from multiple professional societies. Some providers may only resort to VL after failed attempts with DL, contrary to guidelines that suggest considering VL earlier in these scenarios. (3) Underutilization of apneic oxygenation during pediatric difficult intubation. (4) Inconsistent definitions of what defines a difficult tracheal intubation. This may represent a hidden threat to patient safety as inconsistent documentation of difficult airway across providers may result.

6 | Limitations

This study has multiple limitations. First, despite the mobile-friendly survey design and multiple reminder emails sent to the society members, the low response rate and uneven distribution across participating pediatric anesthesia organizations may have resulted in bias. For instance, there was a low response rate from members of IAPA; thus, the described VL practice among the members in IAPA as reported in this survey should be interpreted with caution. Survey participation could be related to accessibility of or willingness to use VL. For instance, participation was lower in younger anesthesiologists, who may be more likely to use new technologies in caring for patients; responders who routinely care for more complex patients or work in a large institution may also be more likely to choose VL as the first-line intubation instrument. However, this is the largest survey to date and the only one with participants from various international pediatric anesthesia societies practicing in different settings. By looking for patterns within the responses we received, the data still provide useful insights after appropriate analysis. Second, tracheal intubation is a complex procedure comprised of two major steps, namely, laryngoscopy and insertion of the ETT. Although the C/L classification is commonly used to describe the difficulty of tracheal intubation, it is insufficient to describe the situation in which it is difficult to insert the ETT despite an easy C/L view by VL. Methods such as creating a scoring system or visual documentation via videotaping ETT insertion were not assessed in this survey. Finally, the data collected reflect subjective opinions and may not be reflective of clinical practice or actual availability of VL.

7 | Conclusions

This study provides an updated snapshot of VL adoption in pediatric anesthesia from members of multiple pediatric anesthesia societies. VL appears to be highly available in most main ORs and non-OR settings, but its availability may be more limited in countries with fewer resources. Despite literature supporting its use and society recommendations, adoption of VL and apneic oxygenation for managing difficult tracheal intubations was lower than expected. Experience with VL and VL availability may also influence how anesthesia providers grade and document the pediatric airway difficulty, resulting in undesired heterogeneity and a patient safety risk. Efforts to address these issues at the level of the individual practitioner, anesthesia society, and institution level are needed to improve adherence to recommendations in pediatric anesthesia practice.

Author Contributions

Conception and design of the survey: all authors. Data collection, extraction, and analysis: W.B., Y.Y., M.T., and G.M. Data interpretation and manuscript drafting: all authors. Manuscript review and editing, and final approval: all authors.

Acknowledgments

The authors thank the executive board members from the PeDI Registry Group, SPA and members from the Scientific Committee of the Society for APAGBI for their input to the questionnaire. The authors wish to thank the following personnel for their assistance in distributing the survey to their corresponding society members: Kim Battle to the members of SPA, Neerja Bhardwaj to the members of IAPA, Nicola Clausen to the members of ESPA, Hannah Gill and Philip Arnold to the members of APAGBI, Fiona Taverner to the members of SPANZA, and Julie Yu to the members of CPAS.

Ethics Statement

This survey was reviewed by the University of Michigan Institutional Review Board and the requirement for informed consent were waived (HUM00226446).

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from Qualtrics, University of Michigan. Restrictions apply to the availability of these data, which were used under license for this study. Data are available from the author(s) with the permission of Qualtrics, University of Michigan.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.