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Respiration and the Airway

A comparison of videolaryngoscopy using standard blades or non-standard blades in children in the Paediatric Difficult Intubation Registry

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Abstract

Background: The design of a videolaryngoscope blade may affect its efficacy. We classified videolaryngoscope blades as standard and non-standard shapes to compare their efficacy performing tracheal intubation in children enrolled in the Paediatric Difficult Intubation Registry.

Methods: Cases entered in the Registry from March 2017 to January 2020 were analysed. We compared the success rates of initial and eventual tracheal intubation, complications, and technical difficulties between the two groups and by weight stratification.

Results: Videolaryngoscopy was used in 1313 patients. Standard and non-standard blades were used in 529 and 740 patients, respectively. Both types were used in 44 patients. In children weighing <5 kg, standard blades had significantly greater success than non-standard blades at initial (51% *vs* 26%, $P=0.002$) and eventual (81% *vs* 58%, $P=0.002$) attempts at tracheal intubation. In multivariable logistic regression analysis, standard blades had 3-fold greater odds of success at initial tracheal intubations compared with non-standard blades (adjusted odds ratio 3.0, 95% confidence interval): 1.32–6.86, $P=0.0009$). Standard blades had 2.6-fold greater odds of success at eventual tracheal intubation compared with non-standard blades in children weighing <5 kg (adjusted odds ratio 2.6, 95% confidence interval: 1.08–6.25, $P=0.033$). There was no significant difference found in children weighing ≥5 kg.

Conclusions: In infants weighing <5 kg, videolaryngoscopy with standard blades was associated with a significantly greater success rate than videolaryngoscopy with non-standard blades. Videolaryngoscopy with a standard blade is a sensible choice for tracheal intubation in children who weigh <5 kg.

Keywords: airway; difficult intubation; infant; neonate; paediatric; videolaryngoscopy

Editor's key points

- Videolaryngoscopes are useful in tracheal intubation in adults and in children, but it is not clear whether or not there are differences in efficacies between the different types of videolaryngoscopes in children.
- There were no significant differences in the efficacies of different types of videolaryngoscopes in children weighing 5 kg or greater.
- In children weighing less than 5 kg, videolaryngoscopes with 'standard' blades were more effective than those with 'non-standard' blades.

Tracheal intubation using direct laryngoscopy becomes difficult when a view of the glottis is unattainable. Videolaryngoscopy allows users to view the glottis indirectly and improves the success rate of tracheal intubation in children in whom there is a concern of unsuccessful direct laryngoscopy.[1,2] At present, there is no universally accepted classification of videolaryngoscopes. We, and others,[3] find classifying videolaryngoscopes based on the design of their blades intuitive and have separated videolaryngoscopes into standard or non-standard blades (Fig. 1).

Videolaryngoscopes with standard blades are similar in shape and design to blades used for conventional direct laryngoscopy. Videolaryngoscopy with a standard blade can be used to perform direct laryngoscopy, video-assisted direct laryngoscopy, or indirect laryngoscopy. During video-assisted direct laryngoscopy,[4] the intubating clinician performs direct laryngoscopy as a colleague observes the screen. The observer can provide coaching, assistance, and confirmation of successful placement of the tracheal tube. With indirect laryngoscopy, the intubating clinician views the larynx, and performs tracheal intubation using the screen.

Videolaryngoscopes with non-standard blades are more acutely curved than standard blades and are intended to follow the natural path of the patient's airway.[5] A videolaryngoscope with a non-standard blade is designed to obtain an indirect view of the glottis and not to perform direct laryngoscopy.

The design of videolaryngoscope blades may affect the success or failure of tracheal intubation in children. There are limited data to guide clinicians in their choice of videolaryngoscope. Studies examining the use of videolaryngoscopy for tracheal intubation rarely distinguish between different blade designs.[6–8] The distinction between videolaryngoscopy with standard and non-standard blades is clinically relevant, as the skills and techniques required to use them successfully differ.[9]

This study's primary aim was to compare the success rates of tracheal intubation between videolaryngoscopes with standard *vs* non-standard blades. Our secondary aims were to compare complications, technical difficulties, and effectiveness in achieving glottic views with their associated success rates for tracheal intubation between the two device

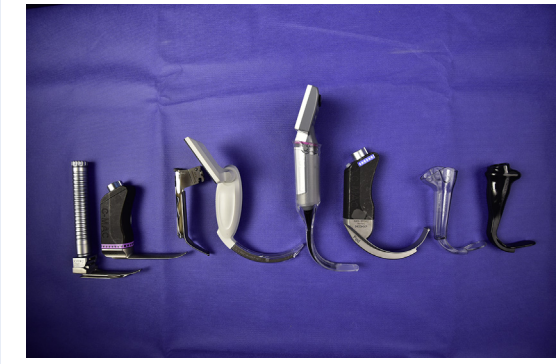

Fig 1. Direct laryngoscopy and videolaryngoscopy blades showing some of the different angulations of the blades that are available. From left to right: Miller 1 DL blade, Storz C-Mac Miller 1 VL blade, Truview EVO, McGrath series 5 Mac 3 blade, King Vision VL blade, Storz C-Mac Pedi-D blade, Glidescope Cobalt AVL sheath, Glidescope Spectrum blade.

categories. We hypothesised that videolaryngoscopy with non-standard blades would have higher success rates for tracheal intubation and provide better laryngeal views than standard blades in children within the Paediatric Difficult Intubation Registry (PeDI-R).

Methods

Approval for this retrospective, observational study was granted by a multi-institutional, shared agreement as part of the PeDI-R through Boston Children's Hospital's Institutional Review Board. The PeDI-R is a collaborative, multicentre, international registry, created under the auspices of the Society for Paediatric Anaesthesia to collect data about children in whom intubating the trachea is difficult. When a centre joins the collaborative, they enter into a data-sharing agreement that includes permission for an Institutional Review Board at any centre within the collaborative to approve studies using the data within the registry. Any study proposal must first be presented to the Executive Committee of the PeDI Collaborative for approval.

Data submitted by 28 institutions into the PeDI-R from March 2017 to January 2020 were analysed. Data were collected from the clinicians who cared for the patients and then verified by the site's representatives for the PeDI-R. Data were stored in a central, secure, online database hosted at the Children's Hospital of Philadelphia and audited monthly for accuracy.

Children <18 yr of age with the following entry criteria were included: direct laryngoscopy had a poor view: an attending (consultant) anaesthetist or otorhinolaryngologist obtains a grade 3 or 4 Cormack and Lehane view[10] with a direct laryngoscopy that was performed during the case; direct laryngoscopy was physically impossible: limiting mouth opening; tracheal intubation using direct laryngoscopy was not possible because of anatomical abnormality; direct laryngoscopy was recently unsuccessful: tracheal intubation using direct laryngoscopy had failed within the preceding 6 months; and direct laryngoscopy was suspected to be difficult or harmful: the attending anaesthesiologist chose an alternative technique after determining that performing a direct laryngoscopy was inappropriate because of a low chance of success and a perceived increased risk of harm.

We categorised videolaryngoscopes into two cohorts, standard and non-standard blades, as follows:

Standard blades: Macintosh and Miller versions of Glidescope (Verathon Inc, Bothell, WA, USA), McGrath (Medtronic, Minneapolis, MN, USA), Storz CMAC (Karl Storz SE, Tuttlingen, Germany) and Direct Coupled Interface (DCI), UE Scope (UE Medical Devices Inc. Newton, MA, USA), and other videolaryngoscopes with standard blades.

Non-standard blades: Airtraq (Prodol Meditec, Bilbao, Spain), Glidescope (Verathon Inc, Bothell, WA, USA), Storz CMAC (Karl Storz SE, Tuttlingen, Germany), UE Scope (UE Medical Devices Inc. Newton, MA, USA), King VL (Ambu A/S, Ballerup, Denmark), McGrath (Medtronic, Minneapolis, MN, USA), Pentax airway scope (Nihon Khoden, Tokyo, Japan), and other videolaryngoscopes with non-standard blades.

Primary outcomes

Initial success

The number of patients in whom the first attempt at tracheal intubation with a given device was successful, divided by the total number of patients in whom the device was attempted. This initial use of the device may have occurred following attempts with other tracheal intubation techniques.

Eventual success

The number of patients in whom the device was successfully used for tracheal intubation divided by the total number of patients in whom the device was attempted.

Multiple studies, including our previous analyses from the PeDI-R and data from the neonatal intensive care setting, have shown that lower patient weights are associated with increased rates of failure and complications during tracheal intubation.[1,2,11,12] Therefore, we stratified our analysis by patient weight: <5 kg, from 5 to <10 kg, from 10 to <30 kg, and ≥30 kg. Subgroup analysis stratified by weight was also performed in patients with documented unsuccessful direct laryngoscopy (PeDI-R entry criteria 1 and 3).

Secondary outcomes

Complications

Complications were analysed on a per attempt basis for each device cohort, modified from the operational definitions used in the National Emergency Airway Registry for Children (NEAR4KIDS).[13] We examined the association of patient variables as detailed in the Statistical methods section and the total number of attempts at tracheal intubation, with any complication.

Technical difficulties

Technical difficulties were described on a per attempt basis by the clinicians performing the intubations. These included airway activation (e.g. coughing), fogging of the camera, heavy secretions, and difficulty directing the tracheal tube despite an adequate view of the glottis.

Table 1 Patient characteristics.

Variable	All patients (non-crossover) (n=1269)	Videolaryngoscopes with standard blades (n=529)	Videolaryngoscopes with non-standard blades (n=740)	P-value
Age (yr)	6 (1, 12)	3 (0, 10)	8 (2, 13)	**<0.001***
Weight (kg)	18.2 (8.7, 35.3)	12.7 (6.2, 28.1)	22.8 (11.3, 39)	**<0.001***
Sex, n (%)				0.317
Female	539 (42)	216 (41)	323 (44)	
Male	730 (58)	313 (59)	417 (56)	
ASA physical status, n (%)				**<0.001***
1	26 (2)	12 (2)	14 (2)	
2	308 (24)	92 (17)	216 (29)	
3	782 (62)	349 (66)	433 (59)	
4	147 (12)	74 (14)	73 (10)	
5	5 (0.4)	1 (0.2)	4 (0.5)	
Criteria for entry, n (%)				0.138
1	239 (19)	95 (18)	144 (19)	
2	68 (5)	21 (4)	47 (6)	
3	93 (7)	45 (9)	48 (6)	
4	869 (68)	368 (70)	501 (68)	
Physical exam, n (%)				0.076
Normal	297 (23)	137 (26)	160 (22)	
Abnormal	972 (77)	392 (74)	580 (78)	
Syndromic, n (%)				0.99
Yes	919 (72)	383 (72)	536 (72)	
No	350 (28)	146 (28)	204 (28)	
Anticipated difficulty, n (%)				0.469
Yes	1088 (86)	458 (87)	630 (85)	
No	181 (14)	71 (13)	110 (15)	
Neuromuscular blocking drugs, n (%)				**<0.001***
Yes	745 (59)	364 (69)	381 (51)	
No	524 (41)	165 (31)	359 (49)	

Data are presented as total number of non-crossover patients with videolaryngoscopes with standard blades and videolaryngoscopes with non-standard blades.
Values inside the brackets for age and for weight are the interquartile ranges (25th percentile, 75th percentile).
*Statistically significant.

Documented glottic view

Glottic view during an attempt at tracheal intubation was recorded using the modified Cormack and Lehane grading system.[10,14,15] Success rates of attempts at tracheal intubation with a documented modified Cormack and Lehane grade 1 or 2a view were analysed.

Crossover patients

Patients in whom both device categories were used in the same encounter. These were evaluated separately to prevent the repeat analysis of the same encounter within each device group.

Statistical analysis

Patient characteristics are presented as medians and interquartile ranges for continuous data and as frequencies and percentages for categorical data. Univariate comparisons in patients with and without initial or eventual tracheal intubation success were made using the non-parametric Wilcoxon rank-sum test for continuous variables, Fisher's exact test for binary data, and the χ^2 test for categorical variables. A multivariable modelling strategy using Generalised Estimating Equations was implemented to determine the independent associations between covariates and successful tracheal intubation while clustering by site using a binomial family and logit link function for correlated data. Stratified analysis by body weight category was performed to compare success rates of tracheal intubation between standard and non-standard blades by using Fisher's exact test or the χ^2 test. Generalised Estimating Equations modelling was used to determine independent association between device type and initial and eventual tracheal success while accounting for nesting within sites and adjusting for baseline covariates. Each model was adjusted for the following baseline covariates: age, weight, sex, ASA physical status classification, PeDI-R criteria for entry, physical exam, presence of a syndrome, anticipated difficulty, and neuromuscular blocking drugs.

Model fit was assessed using the Hosmer-Lemeshow goodness-of-fit test,[16] with $P>0.05$ considered to represent good model fit to the data. The c-index was calculated for the multivariable models for patients <5 kg to assess model discrimination, with values >0.700 representing good model performance. Complications and technical difficulties were presented using frequencies and percentages of the tracheal intubation attempt level, with the standard and non-standard blade groups compared using Fisher's exact test or the χ^2 test. To reduce the risk of type I error as a result of multiple hypothesis testing, we elected to implement an adjusted significance threshold of $P<0.01$ to determine statistical significance for the analysis of complications. Multivariable Generalized

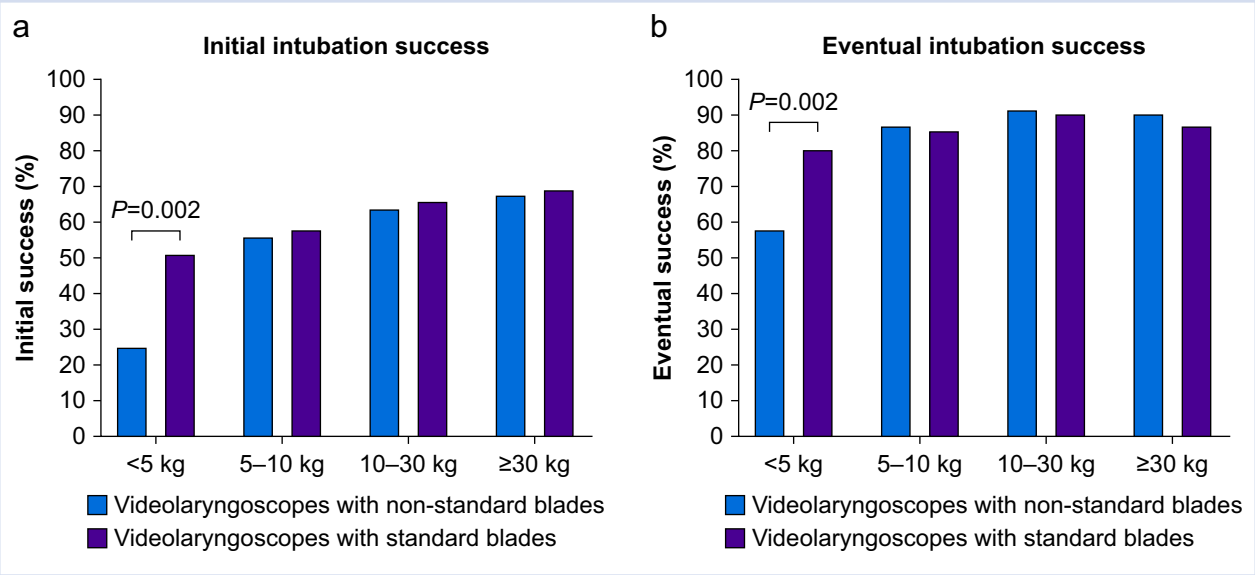

Fig 2. Comparison of initial (a) and eventual (b) intubation success rates using videolaryngoscopy with standard and non-standard blades, stratified by weight category. The weight categories presented are <5 kg, from 5 to <10 kg, from 10 to <30 kg, and ≥30 kg. Across all weight categories combined, the overall initial intubation success rates were 62% in the standard blade group and 62% in the non-standard blade group. The overall eventual intubation success rates were 87% with standard blades and 89% with non-standard blades. Patients who weighed <5 kg intubated using videolaryngoscopy with standard blades had significantly higher rates of initial intubation success (51% *vs* 26%; *P*=0.002), and eventual intubation success (81% *vs* 58%; *P*=0.002) when compared with videolaryngoscopy with non-standard blades.

Estimating Equations modelling was used to assess independent predictors of any complication while accounting for multiple attempts from the same patient.[17] Results of all multivariable Generalized Estimating Equations analyses are presented using adjusted odds ratios (aOR) with corresponding Wald 95% confidence intervals (CI) and *P*-values, and results are graphically depicted using forest plots. Comparisons regarding achieving a modified Cormack and Lehane 2a or better view by type of blade were performed using Fisher's exact test. All statistical analyses were performed using Stata (version 16.0, StataCorp LLC, College Station, TX, USA). A two-tailed alpha level of 0.05 was used to determine statistical significance.

Sample size considerations

A sample size of 55 patients per group will provide more than 80% power for detecting a moderate odds ratio of 2.5 for initial and eventual tracheal success rates comparing the non-standard *vs* standard device groups, assuming a two-tailed 5% alpha level using logistic regression analysis. Therefore, the sample sizes in each weight category provided sufficient statistical power for detecting moderate associations. Power and sample size calculations were performed using nQuery Advisor software (version 8.2, Statistical Solutions Ltd, Cork, Ireland).

Results

Between March 2017 and January 2020, videolaryngoscopy was used in 1313 patients. Non-standard blades were used in 740 patients, whereas standard blades were used in 529 patients. Both types of videolaryngoscopes were used in 44 crossover patients. Baseline characteristics for non-crossover patients (Table 1) showed that patients in the standard blade group were significantly different in that they were younger, weighed less, and had a higher American Society of Anesthesiologists (ASA) physical status and use of neuromuscular blocking drugs. Trainees performed 55% of tracheal intubation attempts in the standard blade group and 53% in the non-standard blade group.

Primary outcomes

Initial success

All patients: there was no significant difference in success rates for initial tracheal intubation between the standard and non-standard blade groups: 327/529 (62%) and 455/740 (62%), respectively, (*P*=0.906). In multivariable logistic regression analysis, increasing weight and entry criterion 4 (direct laryngoscopy was suspected to be difficult or harmful) were significantly associated with successful initial tracheal intubation.

Weight stratified analysis: success rates for initial tracheal intubation in patients weighing ≥5 kg were not significantly different between the standard and non-standard blade groups (Fig. 2). In patients weighing <5 kg, videolaryngoscopy with a standard blade had significantly higher initial success than a non-standard blade: 54/106 (51%) *vs* 14/55 (26%), *P*=0.002 (Fig. 2). In multivariable logistic regression analysis of patients weighing <5 kg, videolaryngoscopy with a standard blade had three times the odds of successful initial tracheal intubation compared with a non-standard blade (aOR 3.0, 95% CI: 1.32–6.86, *P*=0.0009) (Fig. 3).

Subgroup analysis of patients with recently documented unsuccessful direct laryngoscopy (PeDI-R entry criteria 1 and 3, respectively): there were no significant differences in success rates of initial tracheal intubation between device cohorts in any

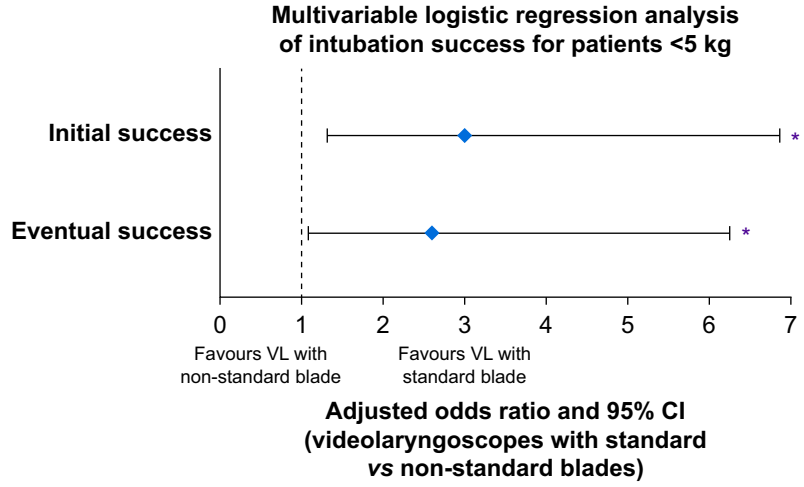

Fig 3. Forest plot displaying the multivariable adjusted regression analysis results for comparing videolaryngoscopy with standard blades to videolaryngoscopy with non-standard blades on initial and eventual intubation success in patients weighing <5 kg. Multivariable modelling was done using generalised estimating equations in order to incorporate site ID as a random effect and using a binomial family and logit link function. Each model was fit using patients weighing <5 kg and adjusted for the following baseline covariates: age, weight, sex, ASA status, criteria for entry, physical exam, presence of a syndrome, anticipated difficulty, and neuromuscular blocking drugs. The green asterisks denote significantly higher adjusted odds of initial and eventual intubation success using videolaryngoscopes with standard blades as compared with videolaryngoscopes with non-standard blades. VL, videolaryngoscope.

weight stratified subgroup. This included patients weighing <5 kg: standard blades, 13/34 (38%) *vs* non-standard blades, 6/28 (21%) $P=0.153$.

Eventual success

All patients: videolaryngoscopy with standard and non-standard blades had similar success rates for eventual tracheal intubation: 460/529 (87%) and 655/740 (89%), respectively ($P=0.402$). By multivariable logistic regression analysis, greater weight, entry criterion 4 (direct laryngoscopy was suspected to be difficult or harmful), normal physical exam, and ASA 2 classification, were significantly associated with eventual success at tracheal intubation. The device category was not associated with eventual success at tracheal intubation.

Weight stratified analysis: eventual success rates in patients weighing ≥5 kg were not significantly different between the device cohorts (Fig. 2). In patients weighing <5 kg, standard blades had a significantly higher rate of eventual success at tracheal intubation than non-standard blades: 86/106 (81%) *vs* 32/55 (58%), respectively, $P=0.002$ (Fig. 2). By multivariable logistic regression analysis, standard blades had about two and a half times the odds of eventual tracheal intubation success compared with non-standard blades in patients weighing <5 kg (aOR 2.6, 95% CI: 1.08–6.25, $P=0.033$) (Fig. 3).

Subgroup analysis of patients with recently documented unsuccessful direct laryngoscopy (PeDI-R entry criteria 1 and 3): eventual success at tracheal intubation in patients weighing ≥5 kg was not significantly different between groups using the two different types of blades. In patients weighing <5 kg, standard blades had a significantly higher eventual success rate than non-standard blades: 23/34 (68%) *vs* 10/28 (36%), $P=0.012$.

Crossover patients: after failed videolaryngoscopy, 154/1313 (12%) patients had rescue attempts with non-videolaryngoscopy techniques, whereas 44/1313 (3%) patients had attempts with the alternate type of videolaryngoscope blade. Initial success rates of standard *vs* non-standard blades were 6/44 (14%) and 27/44 (61%), respectively ($P<0.001$). Eventual success rates were seven/44 (16%) with standard and 30/44 (68%) with non-standard blades ($P<0.001$).

Secondary outcomes

Complications

At least one complication occurred in 222/1269 (17%) patients during 1783 attempts at intubation. In univariate analysis, there were no significant differences in complications (Table 2). In multivariable analysis, each additional attempt at tracheal intubation was associated with nearly two times the odds of having any complication (aOR 1.96, 95% CI: 1.73–2.22, $P<0.001$). More than two attempts were associated with nearly six times the odds of having any complication (aOR 5.81, 95% CI: 4.12–8.21, $P<0.001$).

Technical difficulties

In univariate analysis, difficulty inserting the tracheal tube despite the intubating clinician stating they had an adequate view of the glottis, occurred in significantly fewer attempts with standard blades 125/734 (17%) than with non-standard blades 281/1049 (27%) ($P<0.001$) (Table 2).

Documented glottic view

In all patients, videolaryngoscopy achieved a modified Cormack and Lehane 2a or better view in 457/734 (62%) attempts with standard blades, *vs* 829/1049 (79%) attempts with non-standard blades ($P<0.001$). Patients who had videolaryngoscopy with standard and non-standard blades were

Table 2 Complications and technical difficulties (non-crossover patients).

Complication	Videolaryngoscopes with standard blades (n=734), n (%)	Videolaryngoscopes with non-standard blades (n=1049), n (%)	P-value
Oesophageal intubation immediate recognition	10 (1.4)	6 (0.6)	0.123
Oesophageal intubation delayed recognition	0 (0)	0 (0)	0.999
Epistaxis	2 (0.3)	2 (0.2)	0.999
Aspiration	0 (0)	0 (0)	0.999
Major airway trauma	0 (0)	6 (0.6)	0.046
Minor airway trauma	9 (1.2)	10 (1)	0.642
Laryngospasm	3 (0.4)	4 (0.4)	0.999
Bronchospasm	1 (0.1)	4 (0.4)	0.654
Pharyngeal bleeding	11 (1.5)	31 (3)	0.056
Hypoxaemia	43 (5.9)	57 (5.4)	0.701
Cardiac arrest	2 (0.3)	1 (0.1)	0.572
Pneumothorax	0 (0)	0 (0)	0.999
Arrhythmia	1 (0.1)	0 (0)	0.419
Death	0 (0)	1 (0.1)	0.999
Vomiting	0 (0)	1 (0.1)	0.999
Other complication	10 (1.4)	15 (1.4)	0.905
Any complication	75 (10.2)	117 (11.1)	0.531
Technical difficulties	**Videolaryngoscopes with standard blades (n=734), n (%)**	**Videolaryngoscopes with non-standard blades (n=1049), n (%)**	**P-value**
Airway activation	8 (1.1)	15 (1.4)	0.671
Difficulty directing tracheal tube despite adequate view,	125 (17)	281 (26.8)	**<0.001***
Fogging	8 (1.1)	20 (1.9)	0.245
Heavy secretions	41 (5.6)	59 (5.6)	0.999
Other technical difficulty	50 (6.8)	91 (8.7)	0.151
Any technical difficulty	207 (28.2)	400 (38.1)	**<0.001***

Data are presented as observed incidence of complications and technical difficulties based on total number of attempts with videolaryngoscopes with standard and non-standard blades.
*Statistically significant.

successfully intubated with a modified Cormack and Lehane 2a or better view in 366/457 (80%) attempts and 590/829 (71%), respectively (P=0.001). In patients weighing <5 kg, a modified Cormack and Lehane 2a or better view was obtained in 101/164 (62%) attempts with standard blades compared with 70/99 (70%) with non-standard blades (P=0.144). Successful intubation in patients weighing <5 kg, given a modified Cormack and Lehane 2a or better view occurred in 67/101 (66%) attempts with standard blades and 27/70 (39%) attempts with non-standard blades (P=0.001).

Crossover group

There were 119 attempts at tracheal intubation in the 44 patients within the crossover group. A modified Cormack and Lehane grade 2a or better view was obtained in 9/63 (14% attempts) with standard blades and 35/56 (63%) with non-standard blades (P<0.001). When a modified Cormack and Lehane grade 2a or better view was obtained, the success rates were 4/9 (44%) for standard blades and 23/35 (66%) for non-standard blades (P=0.275).

Discussion

The PeDI-R is the most extensive database containing information about difficult airway management in children. Our study demonstrated that videolaryngoscopy with standard blades was associated with significantly higher success rates for initial and eventual tracheal intubations in children who weigh <5 kg. In children who weigh ≥5 kg, there were no significant differences between the two types of devices. An improvement in success rates of tracheal intubation in neonates and infants is clinically relevant because, when compared with older children and adults, they have limited physiological reserve and are more vulnerable to the rapid development of potentially life-threatening complications. Adding to previous studies,[2,11,18–20] repeated attempts at tracheal intubation were associated with increased complications.

Obtaining a view of the glottis is the vital first step of tracheal intubation. Videolaryngoscopy with non-standard blades had a higher rate of modified Cormack and Lehane grade 1 or 2a views compared with standard blades. However, a good view of the larynx did not guarantee successful tracheal intubation. In patients weighing ≥5 kg, the benefits of improved views with non-standard blades were offset by the greater technical difficulties encountered as clinicians attempted to direct the tracheal tube into the glottis. As a result, success rates between device groups were not significantly different. In patients weighing <5 kg, there was no significant difference in the quality of glottic views obtained with either type of blade. However, in this subgroup, the relative difficulty in converting a good view of the glottis into successful tracheal intubation with a non-standard blade was

more pronounced and may have contributed to the significantly lower rates of success observed with non-standard blades.

There are several potential reasons why tracheal intubation in the presence of an adequate view of the glottis was more difficult with non-standard blades. Videolaryngoscopes with standard blades share the same design as those commonly used for direct laryngoscopy, such as the Miller and Macintosh blades. Familiarity with the design of standard blades may allow the clinician to transfer their existing skills more directly to these devices. In addition, standard blades, by design, create a direct pathway to the glottis, making it easier to place the tracheal tube correctly.[21] In contrast, the curvature of a non-standard blade increases the tracheal tube's angle of approach to the glottis,[9] making it nearly perpendicular to the laryngeal inlet. This challenge is more pronounced in a neonate and infant, as there is a relatively smaller oropharyngeal space available to manoeuvre the tracheal tube and the anterior tilt of the infant larynx directs the glottic opening towards the base of the tongue.[22–24] Our data and our clinical experience support that using videolaryngoscopy with a non-standard blade requires a greater level of expertise with the device to overcome the difficulty of translating an adequate view into a successful intubation.

Clinicians preferred non-videolaryngoscopy rescue techniques after videolaryngoscopes failed. Among the 1313 patients in whom videolaryngoscopes were used, the initial choice of videolaryngoscope was unsuccessful in 198 patients. Only 44 patients then had attempts with the alternative type of videolaryngoscope, whereas 154 patients had non-videolaryngoscope rescue techniques. Most of the crossover cases involved failures of videolaryngoscopes with standard blades to obtain adequate glottic views. The conversion to non-standard blades improved the glottic view and may have accounted for the increased success rates with non-standard blades observed in this subgroup. Although our crossover group had a small number of cases, this suggests that when a standard blade has failed, videolaryngoscopy with a non-standard blade may increase the likelihood of successful tracheal intubation. A potential reason is that this subset of patients had more severe anatomical abnormalities requiring the increased curvature provided by a non-standard blade.

Our data demonstrated similar complication rates between the two types of devices, with a small increase in major trauma (e.g. pharyngeal/laryngeal bleeding, subglottic oedema, the formation of false passages) associated with videolaryngoscopy with a non-standard blade. There were only six cases in which major trauma occurred in the dataset, but all of them occurred while using non-standard blades. This difference in complication rates did not reach our higher threshold for statistical significance set at $P<0.01$. Higher numbers of tracheal intubation attempts were also associated with increased complications, a finding consistent with numerous prior publications.[1,2,19,25] This finding further supports strategies to limit the overall number of attempts at tracheal intubation, including consideration of early transition to alternative techniques in the setting of a failed tracheal intubation.

This retrospective analysis has important limitations. Given the nature of such analyses, confounding factors may exist within the dataset. In order to account for this, multivariable statistical analysis was used to control for potential confounding factors. In particular, there may be cases in which direct laryngoscopy was suspected to be difficult or harmful (PeDI-R entry criterion 4) where the trachea may have been successfully intubated using direct laryngoscopy. Although these specific patients cannot be controlled for directly, our analysis showed no difference in the proportion of the four PeDI-R entry criteria between the two device groups. In addition, subgroup analysis of patients with documented difficult direct laryngoscopy (PeDI-R criteria 1 and 3) supports the overall findings favouring standard blade use in smaller patients.

Clinicians may also only have one type of device available at their centre, particularly for use in children weighing <5 kg. To account for the possible variation in equipment available between different institutions, we controlled for site location. Another limitation is that individual clinicians may differ in their skill and experience with different devices. Although the PeDI-R collects data on the clinician type and their years of experience, these may not be perfect proxies for the level of competence with a device. The PeDI-R also collects data regarding physical abnormalities of the airway (e.g. micrognathia, limited neck mobility), but there remains variability in diagnostic criteria and accuracy among clinicians,[12,26] and the registry does not capture the severity of these exam findings. However, the advantage of an extensive registry is that it provides an insight into real-world practice and can be used to examine current clinical care and outcomes in populations where large scale RCTs are logistically challenging to perform. Management decisions made for a specific patient should be guided by an assessment of individual comorbidities, airway examination, provider experience, and equipment availability.

Conclusions

In patients weighing <5 kg within the PeDI-R, videolaryngoscopy with a standard blade was associated with significantly higher success rates of both initial and eventual tracheal intubation compared with videolaryngoscopy with non-standard blades. Videolaryngoscopy with a standard blade is a reasonable initial choice for tracheal intubation in children who weigh <5 kg and who are at risk of unsuccessful direct laryngoscopy. However, when tracheal intubation using a videolaryngoscope with a standard blade has failed, particularly because of a poor view of the larynx, a videolaryngoscope with a non-standard blade may be used successfully as a rescue device. In patients weighing ≥5 kg, there was no difference in intubation success rates. In addition, complications were associated with a higher number of attempts at intubation, further emphasising the need for airway management strategies that avoid multiple attempts at intubation.

Authors' contributions

JP, RP, MLS, PK: Study conception, study design data collection via the PeDIR, manuscript creation and editing.
SJS, DZ: Study design, statistical analysis design, manuscript author, manuscript editing.
SS, TWT, BvU-S, JEF, PO: Study design, manuscript author and manuscript editing, data collection via the PeDIR.
AGG-M, EK, FC: Manuscript editing, data collection via the PeDIR.
The PeDIR collaborating authors are the Principle Investigators (PIs), and members of the research teams who are responsible for collecting data for the PeDIR in their individual institutions, ensuring data accuracy, and submitting the data to the central database. We are very grateful for the work they do.

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Declarations of interest

PK is a medical advisor to Verathon, Inc. DZ is an member of the associate editorial board of the British Journal of Anaesthesia. The other authors declare that they have no conflicts on interest.

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