Difficult airway prediction in paediatric anaesthesia (Diffair): Prospective observational study

Jozef Klucka^{a#}, Martina Kosinova^{a#}, Milan Kratochvil^a, Lukas Marecek^a, Petra Kovalcikova^b, Milan Urik^c, Petr Stourac^a

Background. The incidence of difficult airway in paediatric patients is lower than that the adult population, and the majority should be predictable.

Aims. The primary aim of this trial was to evaluate the incidence of difficult airway in pediatric patients. The secondary aim was to predict difficult airway in these patients.

Methods. Paediatric patients undergoing elective surgery under general anaesthesia in a tertiary university hospital were examined, and a panel of difficult airway prediction tests was performed. We recorded the incidence, risk factors for difficult airway and events associated with difficult airway together with the sensitivity and specificity of tests for difficult airway and events associated with difficult airway prediction.

Results. We prospectively included 389 paediatric patients. The incidence of difficult airway was 3.6%; the incidence of events associated with difficult airway was 10%. The sensitivity for prediction of events associated with difficult airway during the pre-anaesthesia evaluation was 5.3% with the specificity 93.3%. In the operating room, the sensitivity of prediction was 15% with 97.8% specificity.

Conclusion. We found minimal efficacy for preanaesthesia difficult airway prediction.

Key words: difficult airway, paediatric, prediction

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^aDepartment of Paediatric Anaesthesiology and Intensive Care Medicine, University Hospital Brno and Faculty of Medicine, Masaryk University, Brno, Czech Republic

^bInstitute of Biostatistics and Bioanalyses, Faculty of Medicine, Masaryk University, Brno, Czech Republic

^cDepartment of Paediatric Otorhinolaryngology, University Hospital and Faculty of Medicine, Masaryk University, Brno, Czech Republic

[#]These authors contributed equally to this manuscript

Corresponding author: Petr Stourac, e-mail: petr.stourac@gmail.com

INTRODUCTION

Difficult airways and failure to ventilate and oxygenate the patient is strongly connected with significant morbidity and mortality of both adult and paediatric patients¹⁻⁴. The ideal timing for airway management planning is the outpatient pre-anaesthesia evaluation. The airway evaluation should be based on a patient's history and results of clinical examination using a combination of several tests for difficult airway prediction. The most frequently used prediction tests with reported good effectivity are: Mallampati score, upper lip bite test, cervical spine mobility and thyromental distance (measured in the fold of the patient's fingers)⁵⁻⁷. Age <1 year, ASA III-IV classification, Mallampati III-IV score, obesity (BMI ≥35), ENT and cardiac surgery patient belongs to risk factors for difficult airways⁶⁻⁹.

Difficult airway (DA) is a heterogeneous group that can be divided by the origin of the difficulty: difficult mask ventilation, difficult supraglottic airway insertion, difficult laryngoscopy, difficult intubation and cannot intubate/ cannot oxygenate (CICO) scenario¹⁰. DA is however not precisely defined, and therefore Apfelbaum et al.¹¹ in cooperation with the American society of Anesthesiology tried to redefine DA as Difficult face

mask or supraglottic device ventilation in the situation in which a conventionally trained anaesthesiologist is not capable of achieving adequate ventilation and oxygenation¹¹. Difficult supraglottic device insertion and difficult tracheal intubation are defined by the number of attempts needed for effective airway management – the cut-off in the majority of published data is set at 3 attempts¹¹⁻¹². The published DA incidence in paediatric patients is lower than in adults (difficult face mask ventilation 2.8-6.6%, difficult laryngoscopy 0.06-1.34%) and should be easier to predict¹³. This trial aimed to evaluate the incidence of DA in a selected cohort of patients and to evaluate the options for DA prediction.

MATERIALS AND METHODS

After approval by the local Ethics Committee for randomized trials at the University hospital Brno (9/2017, Jihlavska 20, Brno, Czech Republic, Chairperson – PharmDr. Kozáková Šárka, MBA) and trial registration in clinicaltrials.gov (NCT03404453), we included patients scheduled for elective diagnostic or surgical procedures under general anaesthesia with the need for airway management (face mask, laryngeal mask, tracheal intubation).

The study period was from 1. 1. 2018 to 30. 6. 2018. We did not require informed consent for participation according to the decision of the Ethics committee due to the observational design of the trial. We recruited patients during the outpatient pre-anaesthesia evaluation and evaluated them by clinical examination (weight, height) and a panel of prediction test (thyromental distance, upper lip bite test, inter incisor gap, cervical spine mobility and Mallampati score). We measured the distance in centimetres and fold of the patient's middle finger width. We allocated the patient according to the pre anaesthesia evaluation into one of the three groups based on the clinician's decision: A (low risk), B (intermediate risk), C (high risk). In the operating room (OR), the patients were evaluated by the anaesthesiologist just prior to the anaesthesia and they were allocated to three groups (based on the clinician's decision): A, B, C and the airway management plan was defined. After anaesthesia induction and securing the airway, the airway management was evaluated considering the type of induction, type of airway device (face mask, supraglottic device, uncuffed or cuffed tracheal tube), the position of the head, Cormack – Lehane score (during direct laryngoscopy) and number of attempts needed for successful airway. We recorded the incidence of bradycardia (less than 50 beat per minute) and desaturation (oxygen saturation measured by oxygen saturation probe less than 90%). The primary outcome was the incidence of DA defined as difficult face mask ventilation, difficult intubation (Cormack-Lehane 3 and 4, intubation at third and over the third attempt), difficult laryngeal mask insertion (more than two attempts) and the presence of CICO scenario. Events associated with difficult airway (EADA) were defined as at least three attempts needed for airway management, Cormack-Lehane 3-4, difficult intubation, difficult mask ventilation, airway evaluation B or C after securing the airway, bronchoscope or videolaryngoscope for airway management, bradycardia during airway management (<50 beats/minute), desaturation <90% SaTO₂ (measured by pulse oximetry). The secondary outcome was the efficacy of difficult airway prediction during pre-anaesthesia evaluation and before anaesthesia induction. For the statistical analysis, descriptive statistical methods were used (using the 95% CI, confidence interval). The prediction effectivity was calculated using the Mann-Whitney and Fischer-exact test and using logistic regression analysis for DA and for EADA (using the $P \leq 0.05$ cut-off).

RESULTS

During the selected period, we included 399 patients in the study and analysed 389 patients after exclusion of 10 cases (insufficient data). The incidence of DA in our cohort was 3.6% (95% CI 2.1 to 5.8%). There was no statistically significant difference between normal and DA considering the age, weight and height of the patients and all selected prediction tests: Mallampati score, upper lip bite test, thyromental distance, inter incisor gap and cervical spine mobility before anaesthesia induction,

clinical evaluation of the airway during the outpatient pre-anaesthesia evaluation and in the OR (Table 1). The neutral head position was associated with a lower incidence of DA ($P=0.022$). The age category (infant, toddler, pre-school age, young school age, older school age and adolescence) was not associated with overall difficult airway incidence, or DA and/or EADA incidence ($P=0.313$ nad 0.202) (Table 2). There was no statistically significant association between clinical parameters, the prediction tests and incidence of DA from the logistic regression analysis (Table 3).

Considering all listed clinically relevant parameters as EADA (at least three attempts needed for airway management, Cormack-Lehane 3-4, difficult intubation, difficult mask ventilation, airway evaluation B or C after securing the airway, bronchoscope or videolaryngoscope for airway management, bradycardia during airway management (<50 beats/minute), desaturation <90% SaTO₂) the incidence of EADA was 10% ($n=39/389$, 95% CI 7.3 to 13.3%). When considering the risk factors for EADA, the only statistically significant difference was patient's airway evaluation in the OR as B ($P=0.005$) and the head in the wedged position before anaesthesia induction ($P=0.044$) (Table 4). After logistic regression analysis for EADA incidence, the statistically significant identified risk factors were limited mobility of the cervical spine (limited flexion, limited extension, or free flexion and not recorded extension) with the odds ratio 2.45 ($P=0.028$), airway evaluation B in the OR with the odds ratio 6.95 ($P=0.002$) and neutral head position before anaesthesia induction with odds ratio 0.33 ($P=0.024$) (Table 5). The sensitivity of EADA prediction during pre anaesthesia evaluation was 5.3 % (95% CI 0.1 to 26.0%) with specificity of 93.3% (95% CI 89.9 to 95.8%) which was lower than the EADA prediction during pre-induction evaluation in the OR – sensitivity of 15% (95% CI 3.2 to 37.9%) and specificity of 97.8% (95% CI 95.5 to 99.1%).

DISCUSSION

Airway management difficulties or failure is considered as one major factor associated with perioperative complications^{1,2}. Morbidity and mortality in adult and paediatric patients are directly linked to difficult airways¹⁴⁻¹⁵. Therefore, the anaesthesia providers should be appropriately trained on how to proceed in difficult airway scenarios and local guidelines should be implemented in all anaesthesia centres. The published incidence of difficult airway in paediatric patients is variable given the diversity of DA definition. The reported incidence of difficult airway in paediatric patients is low¹⁵, but the incidence of difficult bag-mask ventilation may be up to 7% (ref.¹⁶) and difficult direct laryngoscopy incidence up to 3% (ref.^{8,17}). The overall incidence of difficult airway in the selected cohort of patients was 3.6%, which is consistent with previously published data¹³. However, reported airway-related adverse events and mortality in paediatric anaesthesia is higher than in adults^{2,18}. This reality in combination with the variable definition of the difficult airway

Table 1. Prediction tests and clinical evaluation for Normal airway and Difficult airway.

Evaluation	n	NA (n = 375)		n	DA (n = 14)		P
		Mean (SD)	Median (min to max)		Mean (SD)	Median (min to max)	
Age (years)	369	6.7 (4.1)	5.0 (0.3 to 19.0)	14	6.0 (4.7)	4.0 (0.5 to 18.0)	0.231
Height (cm)	354	124 (24)	118 (54 to 196)	14	115 (32)	109 (59 to 187)	0.142
Weight (kg)	374	28 (17)	20 (4 to 105)	14	28 (20)	21 (6 to 77)	0.710
Width of the finger (cm)	361	1.3 (0.3)	1.2 (0.4 to 2.3)	12	1.2 (0.3)	1.2 (0.6 to 1.7)	0.702
Interincisor gap (cm)	353	4.1 (0.9)	4.0 (1.5 to 7.0)	11	4.0 (0.8)	4.0 (3.0 to 6.0)	0.583
Interincisor gap (fingers)	352	3.3 (1.0)	3.3 (0.0 to 8.8)	11	3.2 (0.6)	3.3 (2.5 to 4.1)	0.845
Thyreomental distance (cm)	352	6.4 (1.9)	6.0 (2.5 to 13.0)	11	6.5 (1.8)	6.0 (4.5 to 11.0)	0.938
Thyreomental distance (fingers)	353	5.2 (2.0)	5.0 (0.0 to 16.7)	11	5.1 (1.2)	5.4 (3.1 to 6.7)	0.748

Prediction test and clinical evaluation		n	%	n	%	P
Mallampati score	1	255	68.0	11	78.6	0.749
	2	67	17.9	1	7.1	
	3	13	3.5	0	0.0	
	4	2	0.5	0	0.0	
	Not recorded	38	10.1	2	14.3	
Cervical spine mobility (Flexion/ extension)	Free/Free	284	75.7	11	78.6	0.826
	Free/-	48	12.8	1	7.1	
	Free/limited	4	1.1	0	0.0	
	Limited/free	1	0.3	0	0.0	
	Not recorded	38	10.1	2	14.3	
ULB test	Positive	279	74.4	11	78.6	1.000
	Negative	23	6.1	0	0.0	
	Not recorded	73	19.5	3	21.4	
Airway evaluation - outpatient preanaesthesia evaluation [†]	A	343	91.5	12	85.7	0.280
	B	26	6.9	1	7.1	
	C	0	0.0	0	0.0	
	Not recorded	6	1.6	1	7.1	
Airway evaluation - OR [†]	A	352	93.9	13	92.9	0.596
	B	11	2.9	1	7.1	
	C	0	0.0	0	0.0	
	Not recorded	12	3.2	0	0.0	
Head position	Head wedged	247	65.9	14	100.0	0.022
	Neutral position	110	29.3	0	0.0	
	Not recorded	18	4.8	0	0.0	

NA = Normal airway; DA = Difficult airway; SD = Standard deviation; ULB test = Upper lip bite test, OR = operating room

[†] A = low risk, B = intermediate risk, C = high risk

The significant P values are bolded

led us to extend the definition and compare all clinically relevant adverse events connected with difficult airway management (desaturation, bradycardia) – EADA. When compared to the incidence of DA, the incidence of EADA was far higher (10.0%).

The associated risk linked with difficult airway could be partially preventable if patients with difficult airway

were identified during the preanaesthesia evaluation and proper preparation was made before anaesthesia¹⁹. The airway evaluation and patient assessment is an integral part of the preanaesthesia visit²⁰. The clinical examination, patient history and medical records should be used to predict airway-related complications and clinical examination of the airways should be performed by the an-

Table 2. Difficult airway (DA) and Events associated with difficult airway (EADA) incidence according to the age category.

Age category	Difficult airway	DA		EADA	
		n	% (95% CI)	n	% (95% CI)
All patients (n = 389)*	No	375	96.4 (94.2-97.9)	350	90.0 (86.7-92.7)
	Yes	14	3.6 (2.1-5.8)	39	10.0 (7.3-13.3)
Infant – do 1 years (n = 2)	No	1	50.0 (6.1-93.9)	1	50.0 (6.1-93.9)
	Yes	1	50.0 (6.1-93.9)	1	50.0 (6.1-93.9)
Toddler – 1-2 years (n = 18)	No	18	100.0 (-)	18	100.0 (-)
	Yes	0	0.0 (-)	0	0.0 (-)
Preschool age – 3-5 years (n = 184)	No	176	95.7 (92.0-97.9)	165	89.7 (84.7-93.5)
	Yes	8	4.3 (2.1-8.0)	19	10.3 (6.5-15.3)
Younger school age – 6-10 years (n = 115)	No	112	97.4 (93.2-99.3)	104	90.4 (84.1-94.8)
	Yes	3	2.6 (0.7-6.8)	11	9.6 (5.2-15.9)
Older school age – 11-14 years (n = 38)	No	37	97.4 (88.4-99.7)	33	86.8 (73.5-94.8)
	Yes	1	2.6 (0.3-11.6)	5	13.2 (5.2-26.5)
Adolescence – 15-19 years (n = 26)	No	25	96.2 (83.4-99.6)	23	88.5 (72.3-96.6)
	Yes	1	3.8 (0.4-16.6)	3	11.5 (3.4-27.7)
<i>P</i>		0.313		0.202	

* 6 patients was excluded from analysis due to missing data, DA = Difficult airway; EADA = Events associated with difficult airway

Table 3. Logistic regression analysis for DA prediction and DA incidence.

Clinical parameters and prediction tests		n	odds ratio	95% CI for odds ratio	<i>P</i>
Age (increase by 1 year)		383	0.95	0.82 to 1.10	0.524
Height (increase by 10 cm)		368	0.84	0.65 to 1.09	0.184
Weight (increase by 5 kg)		388	1.01	0.87 to 1.17	0.929
Interincisor gap (increase by 1 finger width)		363	0.83	0.42 to 1.67	0.605
Thyreomental distance (increase by 1 finger width)		364	0.99	0.72 to 1.35	0.936
Mallampati score	1	266	1.00	-	-
	2-4	83	0.28	0.04 to 2.22	0.230
Cervical spine mobility (flexion/extension)	free/free	295	1.00	-	-
	Limited flexion or extension, or free flexion/NR extension	54	0.49	0.06 to 3.85	0.495
ULB test	Positive	290	Cannot be calculated		
	Negative	23			
Airway evaluation - outpatient preanaesthesia evaluation [†]	A	355	1.00	-	-
	B	27	1.10	0.14 to 8.79	0.929
Airway evaluation - OR [†]	A	365	1.00	-	-
	B	12	2.46	0.30 to 20.52	0.405
Head position	Head wedged	261	Cannot be calculated		
	Head neutral position	110			

DA = Difficult airway; CI = Confidential interval; ULB test = Upper lip bite test; OR = operating room; NR = not recorded

[†] A = low risk, B = intermediate risk

aesthesiologist (mouth opening, cervical spine mobility, etc.)²¹. Multiple clinical examinations and tests have been explored for difficult airway prediction. Several difficult airway prediction scores and scales have been used in paediatric population without validation²¹. Although published data describe difficult paediatric airway as easy to predict¹³, no single prediction test (or combination), clinical evaluation or examination of the airway has the

ability to provide a positive prediction. In our cohort only limited cervical spine mobility was associated with very low difficult airway prediction probability. In the literature, several potential risk factors are mentioned such as weight, weight < 10 kg, age and short thyreomental distance¹⁴. The decreasing age of paediatric patients are described as a potential risk factor¹⁵, however in our study overall age, age category (infant, toddler, preschool, basic

Table 4. Prediction test and clinical evaluation for EADA.

Evaluation	NA (n = 350)			EADA (n = 39)			<i>P</i>
	<i>n</i>	Mean (SD)	Median (min to max)	<i>n</i>	Mean (SD)	Median (min to max)	
Age (years)	344	6.6 (4.0)	5.0 (0.3 to 19.0)	39	7.1 (4.5)	5.0 (0.5 to 18.0)	0.648
Height (cm)	331	123 (24)	118 (54 to 196)	37	123 (29)	118 (59 to 187)	0.874
Weight (kg)	349	27 (17)	20 (4 to 105)	39	30 (20)	22 (6 to 80)	0.385
Width of the finger (cm)	336	1.3 (0.3)	1.2 (0.4 to 2.3)	37	1.3 (0.3)	1.2 (0.6 to 2.0)	0.905
Interincisor gap (cm)	329	4.1 (0.9)	4.0 (1.5 to 7.0)	35	4.1 (1.0)	4.0 (3.0 to 7.0)	0.487
Interincisor gap (fingers)	328	3.3 (1.0)	3.3 (0.0 to 8.8)	35	3.2 (0.6)	3.3 (2.3 to 5.0)	0.596
Thyreomental distance (cm)	328	6.4 (1.9)	6.0 (2.5 to 13.0)	35	6.7 (2.0)	6.0 (4.5 to 12.0)	0.542
Thyreomental distance (fingers)	329	5.2 (2.0)	5.0 (0.0 to 16.7)	35	5.3 (1.4)	5.0 (3.1 to 10.0)	0.296

Prediction test and clinical evaluation		<i>n</i>	%	<i>n</i>	%	<i>P</i>
Mallampati score	1	240	68.6	26	66.7	0.690
	2	59	16.9	9	23.1	
	3	13	3.7	0	0.0	
	4	2	0.6	0	0.0	
	Not recorded	36	10.3	4	10.3	
Cervical spine mobility (flexion/ extension)	Free/Free	270	77.1	25	64.1	0.154
	Free/-	40	11.4	9	23.1	
	Free/limited	3	0.9	1	2.6	
	Limited/free	1	0.3	0	0.0	
	Not recorded	36	10.3	4	10.3	
ULB test	Positive	260	74.3	30	76.9	1.000
	Negative	21	6.0	2	5.1	
	Not recorded	69	19.7	7	17.9	
Airway evaluation – outpatient preanaesthesia evaluation†	A	321	91.7	34	87.2	0.356
	B	23	6.6	4	10.3	
	C	0	0.0	0	0.0	
	Not recorded	6	1.7	1	2.6	
Airway evaluation – OR†	A	331	94.6	34	87.2	0.005
	B	7	2.0	5	12.8	
	C	0	0.0	0	0.0	
	Not recorded	12	3.4	0	0.0	
Head position	Head wedged	228	65.1	33	84.6	0.044
	Neutral position	105	30.0	5	12.8	
	Not recorded	17	4.9	1	2.6	

EADA = Events associated with difficult airway; NA = Normal airway; SD = Standard deviation; ULB test = Upper lip bite test, OR = operating room

† A = low risk, B = intermediate risk, C = high risk

The significant *P* values are bolded

school, adolescence) were statistically related to the DA or EADA incidence (Table 1 and Table 2). Difficult airway is directly linked with the syndromic and dysmorphic features such as Pierre Robin sequence, Treacher Collins syndrome, Goldenhar syndrome, mucopolysaccharidosis and others^{14,22-23}. These patients, however represent only a minority of paediatric patients scheduled for acute or elective surgeries in paediatric anaesthesia centres.

Considering the extended EADA criteria, DA in our cohort was associated with the wedged position of the head, limited mobility of the cervical spine and could be predicted from the clinical evaluation of the anaesthe-

siologist in the operating room, however with a sensitivity of only 15%. The efficacy the DA prediction of the anaesthesiologist during outpatient pre-anaesthesia evaluation was even weaker ($P=0.929$ vs $P=0.405$ for DA and $P=0.385$ vs $P=0.002$ for EADA). The limited DA predictability can be partially explained by the absence of validation of the majority of prediction tests on the paediatric population. It should be noted that although some data find paediatric difficult airway rare and easy to predict^{15,24}, the reported incidence of difficult bag mask ventilation is up to 7%¹⁶ and difficult direct laryngoscopy up to 3% (ref.¹⁷) (or even up to 4.7% in infants) (ref.^{3,8}).

Table 5. Logistic regression analysis for EADA prediction and EADA incidence.

Clinical parameters and prediction tests		n	Odds ratio	95% CI for odds ratio	P
Age (increase by 1 year)		383	1.03	0.96 to 1.11	0.425
Height (increase by 10 cm)		368	0.99	0.86 to 1.14	0.931
Weight (increase by 5 kg)		388	1.04	0.95 to 1.13	0.363
Interincisor gap (increase by 1 finger width)		363	0.85	0.57 to 1.26	0.411
Thyreomental distance (increase by 1 finger width)		364	1.04	0.88 to 1.23	0.672
Mallampati score	1	266	1.00	-	-
	2-4	83	1.12	0.50 to 2.50	0.777
Cervical spine mobility (flexion/extension)	free/free	295	1.00	-	-
	Limited flexion or extension, or free flexion/NR extension	54	2.45	1.10 to 5.46	0.028
ULB test	Positive	290	1.00	-	-
	Negative	23	0.83	0.18 to 3.69	0.802
Airway evaluation - outpatient preanaesthesia evaluation†	A	355	1.00	-	-
	B	27	1.64	0.54 to 5.03	0.385
Airway evaluation - OR†	A	365	1.00	-	-
	B	12	6.95	2.09 to 23.10	0.002
Head position	Head wedged	261	1.00	-	-
	Head neutral position	110	0.33	0.12 to 0.87	0.024

EADA = Events associated with difficult airway; ULB test = Upper lip bite test, OR = operating room, NR = Not recorded

† A = low risk, B = intermediate risk

The significant *P* values are bolded

The major limitation of the study is the observational design and the limited number of patients. Despite this limitation, the incidence of 3.6% of DA and 10% for EADA in combination with very limited DA predictability is surprising and demands standardisation of airway evaluation and difficult airway prediction in paediatric anaesthesiology. The main contribution of the study is that despite the low DA incidence (3.6%), the clinically more important EADA incidence was significantly higher (10%), with only minimal options for DA or EADA prediction.

CONCLUSION

Difficult airway incidence in a selected cohort of paediatric patients was 3.6%, and clinically more relevant incidence of events associated with difficult airways (including bradycardia and desaturation during induction) was 10 % with only minimal options for prediction.

ABBREVIATIONS

ASA, American Society of Anesthesiology; BMI, Body mass index; CI, Confidence interval; CICO, Cannot intubate/ cannot oxygenate; DA, Difficult airway; EADA, Events associated with difficult airway; ENT, Ear Nose Throat; OR, Operating room.

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