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Original Article

Flexible bronchoscopy in children: complications and predictive factors

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ABSTRACT

Background. Although flexible bronchoscopy (FB) is frequently performed in children, there is limited information on the potential complications and risk factors. In this study we aimed to evaluate the complications associated with pediatric FB and identify predictors of these complications.

Methods. Patients aged 0-18 years who underwent FB at the Akdeniz University Pediatric Pulmonology Department between February 1, 2015 and June 30, 2023 were included in the study. We retrospectively recorded the patients' demographic data, known diseases, pulmonary function test results, chest computed tomography findings, bronchoscopy time/indication/route/findings, vital signs, minor and major complications associated with the FB procedure, post-procedure intensive care unit admission, procedure and sedation durations, and American Society of Anesthesiologists physical status (ASA-PS) classification, Mallampati score and anticipated need for post-procedural intensive care as evaluated in the pre-procedure anesthesiology consultation.

Results. The study included a total of 292 patients; 157 (53.8%) girls and 135 boys, with a mean age of 9.9±4.8 years. There were a total of 55 FB-related complications (18.8%), 19 major (6.5%) and 36 minor (12.3%), and 10 patients (3.4%) required intensive care unit admission due to the procedure. The most common complication was hypoxia (11.3%). Patient age, height, anticipated need for intensive care, and baseline oxygen saturation values were significant predictors of the development of bronchoscopy-related complications, while patient age, baseline diastolic blood pressure, anticipated need for intensive care, and route of insertion were predictors of major complications after bronchoscopy. ASA-PS score, pulmonary function test values, and procedure/sedation durations had no effect on the development of complications.

Conclusion. Although FB is a fairly safe diagnostic method in children, extra caution regarding possible complications is warranted in young children, when using the nasal route of insertion, or if the patient is evaluated as high-risk in the pre-procedure assessment performed by the anesthesiologist.

Key words: flexible bronchoscopy, complication, laryngeal mask, pediatrics, anesthesia.

Flexible bronchoscopy (FB) is an interventional procedure commonly used by pediatric pulmonologists. FB serves multiple purposes in the diagnosis and treatment of pediatric respiratory diseases. It is generally used diagnostically for anatomical imaging of the respiratory tract in conditions such as stridor, persistent/recurrent wheezing, chronic cough, recurrent pneumonia, suspected foreign body aspiration, hemoptysis, pulmonary hemorrhage, and radiological abnormalities (atelectasis, recurrent/permanent consolidations), but can

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also be used for therapeutic purposes, such as restoring airway patency in patients with mucus plugs, treating alveolar filling disorders (alveolar proteinosis), controlling bleeding, and guiding difficult intubations.[1,2]

Although FB is frequently performed in children, there is limited information about its complications and potential risk factors. Many studies have focused on the clinical importance and areas of application of FB, while few have evaluated the reliability and complications of the procedure.[3] FB is generally considered safe. Nevertheless, it is an invasive intervention that requires anesthesia, and various studies have documented the occurrence of mild or severe complications such as desaturation, airway trauma, and laryngeal spasm. These complications may be related to numerous patient or procedure-related variables. The risk of complications depends on various factors, including the patient's pre-existing disease, their condition during the procedure, and the way the procedure is performed.[1,3]

Our aim in this study was to evaluate the complications associated with the pediatric FB procedure in children and to identify predictors of these complications.

Materials and Methods

Patients and study setting

Patients aged 0-18 years who underwent FB in the Akdeniz University Pediatric Pulmonology Department between February 1, 2015 and June 30, 2023 were included in this retrospective single-centre study. Those who underwent bronchoscopy while hospitalized in the intensive care unit (ICU) were excluded from the study due to the likelihood of comorbidities. We retrospectively examined patient records, bronchoscopy documents, anesthesia consultation notes, anesthesia follow-up charts, laboratory test results, and radiology reports. We evaluated the patients' demographic data, pulmonary function test results, chest computed tomography (CT) findings, indication, duration and findings of bronchoscopy, route of insertion of the bronchoscope, vital signs, bronchoscopy-related complications, need for post-procedure intensive care, duration of procedure and sedation, and anesthetic agents used during the procedure. Body mass index (BMI) percentiles and thresholds for tachycardia, tachypnea, hypotension, and hypertension were determined according to the Centers for Disease Control (CDC) and Pediatric Advanced Life Support (PALS) data.[4,5]

Consultation from the Department of Anesthesiology was requested before bronchoscopy, and the procedure was performed in our Pediatric Chest Diseases Bronchoscopy Unit with a bed ready in the ICU, if deemed necessary by the anesthesiologist, based on their assessment. The patients' American Society of Anesthesiologists physical status classification (ASA-PS) (I: A normal healthy patient; II: A patient with mild systemic disease, III: A patient with severe systemic disease that limits activity but not incapacitating, IV: A patient with incapacitating disease that is a constant threat to life, and V: A moribund patient not expected to survive 24 h with or without surgical operation)[6] and Mallampati score (Class 1: Faucial/tonsillar pillars, uvula and soft palate are all visible; Class 2: Partial visibility of the faucial/tonsillar pillars, uvula and soft palate; Class 3: Base of the uvula, soft and hard palate visible; and Class 4: Only hard palate is visible)[7] were evaluated by the anesthesiologist before the procedure and recorded in the consultation notes, as well as whether they anticipated the need for intensive care were recorded retrospectively.

Anesthesia

Informed consent was obtained from each patient's parents after a detailed explanation of the bronchoscopy procedure in detail. Pediatric Chest Diseases Bronchoscopy Unit was equipped with all necessary resuscitation materials, with continuous monitoring consisting of pulse oximetry, capnography, non-invasive electrocardiogram, and blood pressure

measurement throughout the procedure. The EB530S and EB530P (Fujinon Fujifilm Europe GmbH, Düsseldorf, Germany) devices were used with a bronchoscope tip suitable for the age and weight of the patient (3.8/4.9 mm).

FB under general anesthesia with the use of a laryngeal mask airway (LMA) was predominantly utilized, as it ensured patient comfort, maintained the stability of the upper airway, and provided a less contaminated pathway for the introduction of the bronchoscope into the lower airway. In cases requiring dynamic airway assessment or when suspicion of concomitant upper respiratory tract pathologies existed, the nasal route was preferred. Sedoanalgesia was achieved with sevoflurane, propofol, fentanyl, and rocuronium in cases where an LMA was selected as the route of insertion, or with midazolam, propofol, and ketamine when using the nasal route.

Procedure duration was calculated as the time from the insertion of the bronchoscope tip into the nose or laryngeal mask to its removal from the insertion site after completing the procedure. Total sedation duration was calculated as the time from the administration of the first anesthetic agent to the patient's return to baseline sedation level.[8]

Definition and classification of complications

Minor complication: 1) Mild desaturation during the procedure ($80\% \leq SpO_2 < 90\%$); 2) Laryngospasm or bronchospasm without $SpO_2 < 90\%$; 3) Mild systemic allergic reaction without hypoxia or hypotension; 4) Temporary need for oxygen support after bronchoscopy; 5) Transient cough, stridor, or dyspnea after the procedure; 6) Fever > 38.5 °C after bronchoscopy; 7) Mild bleeding during the procedure.

Major complication: 1) Sustained bradycardia associated with severe desaturation ($SpO_2 < 80\%$) during bronchoscopy; 2) Laryngospasm or bronchospasm with desaturation ($SpO_2 < 90\%$); 3) Severe allergic reaction accompanied by hypoxia or hypotension; 4) Pulmonary or endobronchial bleeding requiring procedure interruption; 5) Need for mechanical ventilation after bronchoscopy; 6) Need for unplanned ICU observation after bronchoscopy; 7) Arterial hypotension requiring intravascular volume expansion or inotropic support; 8) Cardiorespiratory arrest or need for cardiopulmonary resuscitation.[3]

Statistical analysis

Statistical analyses were performed using SPSS version 20 statistical software. Distribution of the variables was assessed using both visual (histograms, probability plots) and analytical methods (Kolmogorov-Smirnov and Shapiro-Wilk tests). The chi-square test was used to compare categorical data, and the Mann-Whitney U test was used to compare continuous data. Variables analyzed with Mann-Whitney U test were summarized using median (interquartile range, Q1-Q3) values, and number and percentage values were given for categorical variables. Logistic regression analysis was performed to determine the association between patient- and procedure-related factors and the occurrence of complications. Variables found to be statistically significant in the univariate logistic regression analysis for the development of complications — namely age, nasal route of bronchoscopy, anticipated ICU need, and initial oxygen saturation — were subsequently included in a multivariate logistic regression model. Due to missing data in some predictor variables, the final multivariate analysis included 278 patients. Among these, 52 patients had complications. Collinearity diagnostics indicated that all parameters had a variance inflation factor (VIF) of 1. The model demonstrated a sensitivity of 13.5% and a specificity of 98.2%. Similarly, for the analysis of major complication development age, nasal route of bronchoscopy, and anticipated ICU need, identified as significant in the univariate logistic regression, were entered into a multivariate logistic regression model. This analysis included 284 patients, of whom 17 had major complications. In this model, all

variables had VIF values of 1, indicating no multicollinearity. The model's sensitivity and specificity were determined to be 5.8% and 99.3%, respectively.

Ethical approval

This study was conducted in line with the principles of the Declaration of Helsinki. Approval was granted by the Akdeniz University Ethics Committee (Approval no KAEK-545; date 19/7/2023).

Results

The study included a total of 292 patients; 157 girls (53.8%) and 135 boys, with a mean age of 9.9±4.8 (range: 0.1-18) years. The patients had a mean BMI of 17.3±3.9, with 63.1% being of normal weight, 23.7% underweight, 8.1% overweight, and 5.1% obese. A total of 172 patients (58.9%) had a known disease, including asthma (n=61, 20.9%), cystic fibrosis (n=24, 8.2%), primary ciliary dyskinesia (n=18, 6.2%), immunodeficiency (n=14, 4.8%), bone marrow transplant (n=13, 4.5%), malignancy (n=13, 4.5%), renal transplant (n=7, 2.4%), operated esophageal atresia (n=6, 2.1%), congenital heart disease (n=6, 2.1%), neuromuscular disease (n=5, 1.7%), interstitial lung disease (n=4, 1.4%), and achondroplasia (n=1, 0.3%). The most common finding on chest CT before bronchoscopy was atelectasis (36%). This was followed by nodular lesion (32.5%) and peribronchial thickening (29.1%). The most common indication for bronchoscopy was chronic cough (33.6%), followed by bronchoalveolar lavage sampling (23.6%) and right middle lobe syndrome/atelectasis (19.2%). Other indications included recurrent pneumonia (11%), hemoptysis (10.3%) and suspected endobronchial lesion (2.3%).

Pre-bronchoscopic data

The potential need for ICU admission after bronchoscopy was noted in the anesthesia department consultation for 55 patients (19.4%). ASA-PS classification was I in 66 patients (29.1%), II in 127 patients (55.9%), III in 33 patients (14.5%), and IV in 1 patient (0.4%). Mallampati score was 1 for 160 patients (76.6%), 2 for 47 patients (22.5%), and 3 for 2 patients (1%). In the 131 patients who were able to perform the pulmonary function test, the mean percent predicted forced expiratory volume in the first second (FEV_1%) was 77.6±24.6, percent predicted forced vital capacity (FVC%) was 71.1±22.7, and the percent predicted maximal mid-expiratory flow rate (MEF25-75%) was 89±34.2. The mean preoperative SpO_2 was 98.1%±2.0%, heart rate was 111±21.5 beats/min, systolic blood pressure was 113.9±13.7 mmHg, diastolic blood pressure was 68.5±11.9 mmHg, and respiratory rate was 23.9±5.3 breaths/min. A total of 116 patients (40.3%) had tachycardia, 49 (17.2%) had tachypnea, 42 (14.8%) had hypertension, and 14 (4.9%) had hypotension.

Bronchoscopy data

The mean duration of bronchoscopy was 19.2±7.8 minutes (range: 6-50) and the duration of sedation was 32.9±10.9 minutes (range: 13-65). The route of insertion used was a laryngeal mask in 266 (91.1%) and the nasal route in 26 patients (8.9%). A total of 108 patients (41.4%) required an additional dose of anesthetic agent during the procedure. Bronchoscopy findings were evaluated as normal in 96 patients. Among the other patients, the most common abnormal bronchoscopy finding was mucus plugs (n=114, 39%). Complications associated with the FB procedure occurred in 55 patients (18.8%). Of these, 19 (6.5%) had major and 36 (12.3%) had minor complications. The most common complication was hypoxia (11.3%). In addition, 10 patients (3.4%) required ICU admission due to the procedure (6 patients had persistent severe desaturation, 2 had bronchospasm, 1 had pulmonary edema, and 1 had respiratory distress due to increased secretions; Table I).

Variables associated with bronchoscopy complications

The demographic and clinical data of patients with and without bronchoscopy-related complications are compared in Table II.

Table I. Bronchoscopy-related data (N=292)

Bronchoscopy findings	n (%)
Mucus plug	114 (39)
Normal	96 (32.9)
Chronic inflammatory changes*	26 (8.9)
Bronchomalacia	21 (7.2)
Bronchial stenosis	5 (1.7)
Endobronchial lesion	5 (1.7)
Tracheal bronchus	4 (1.4)
Tracheomalacia	4 (1.4)
Endobronchial white plaque	3 (1)
Polypoid lesion	3 (1)
Bleeding	3 (1)
Bronchoesophageal fistula	2 (0.7)
Tracheoesophageal fistula	2 (0.7)
Blind ending fistula orifice	2 (0.7)
Foreign body	1 (0.3)
Vocal cord edema	1 (0.3)
Bronchoscopy-related complications	
None	237 (81.2)
Major complications	19 (6.5)
Sustained or bradycardia associated severe desaturation (SpO2 < 80%) during bronchoscopy	12 (4.1)
Need for unplanned intensive care observation after bronchoscopy	10 (3.4)
Bronchospasm with desaturation <90%	4 (1.3)
Bleeding requiring interruption of the procedure	1 (0.3)
Minor complications	36 (12.3)
Mild desaturation (80% ≤ SaO2 < 90%) during bronchoscopy	21 (7.2)
Laryngospasm without desaturation < 90%	7 (2.4)
Bronchospasm without desaturation < 90%	3 (1)
Fever > 38.5 °C after bronchoscopy	2 (0.7)
Mild systemic allergic reaction without hypoxia or arterial hypotension	1 (0.3)
Agitation after anesthesia probably related to medication	1 (0.3)
Mild bleeding during the procedure	1 (0.3)

*Chronic inflammatory changes: erythema, edema, and friability of the bronchial mucosa.

Characteristics associated with the development of any bronchoscopy complication included anticipated post-procedure intensive care need as noted in the anesthesiologist's pre-procedure consultation (p=0.021), younger age (p=0.002), shorter height (p=0.002), lower baseline diastolic blood pressure (p=0.026), nasal route of bronchoscope insertion (p=0.001), and lower baseline oxygen saturation (p=0.012).

When the patients' demographic and clinical data were compared based on the development of major complications, patients with major complications were found to have a significantly lower age (p=0.035) and baseline diastolic blood pressure (p=0.018). A higher Mallampati score (p=0.042), anticipated ICU need (p<0.001), and nasal route of bronchoscopy (p<0.001) were also significantly associated with major complications (Table III).

Table II. Relationship between presence of complications and other parameters (N=292)

	Complication present	Complication absent	p
	n (%)	n (%)	
Sex			0.898
Female	30 (19.1)	127 (80.9)	
Male	25 (18.5)	110 (81.5)	
BMI percentile			0.477
Normal	28 (18.8)	121 (81.2)	
Underweight	9 (16.1)	47 (83.9)	
Overweight	5 (26.3)	14 (73.7)	
Obese	4 (33.3)	8 (66.7)	
Comorbidity			0.301
Yes	29 (16.9)	143 (83.1)	
No	26 (21.7)	94 (78.3)	
ASA-PS classification			0.120
1	9 (13.6)	57 (86.4)	
2	28 (22)	99 (78)	
3	3 (8.8)	31 (93.9)	
Mallampati score			0.180
1	23 (14.4)	137 (85.6)	
2	11 (22.4)	38 (77.6)	
Anticipated ICU need			0.021
Yes	16 (29.1)	39 (70.9)	
No	36 (15.7)	193 (84.3)	
Bronchoscopy route			0.001
Laryngeal mask	44 (16.5)	222 (83.5)	
Nasal	11 (42.3)	15 (57.7)	
Additional dose of anesthetic agent requirement during procedure			0.277
Yes	21 (19.4)	87 (80.6)	
No	22 (14.4)	131 (85.6)	
	Median (Q1-Q3)	Median (Q1-Q3)	
Age (years)	6 (4-13)	10 (7-14)	0.002
Height (cm)	125 (106-155)	143 (124-160)	0.002
Weight (kg)	21 (17-41)	30 (20- 46.5)	0.357
BMI (kg/m^2)	16 (14.4-18.4)	16.8 (14.6-19.5)	0.364
Baseline heart rate (bpm)	113 (102-129)	110 (97-125)	0.143
Baseline systolic BP (mmHg)	112 (100-120)	115 (105-123)	0.234
Baseline diastolic BP (mmHg)	63 (57-73)	69 (60-77)	0.026
Baseline respiratory rate (/min)	24 (20-29)	24 (20-28)	0.269
Baseline oxygen saturation (%)	98 (97-99)	99 (97-100)	0.012
FEV1%	79 (68-92)	77 (56-93)	0.853
FVC%	67 (61-84)	68 (54-86)	0.730
MEF25-75%	93 (72-115)	91 (61-112)	0.595
Procedure duration (min)	20 (15-24)	19 (15-20)	0.216
Sedation duration (min)	30 (25-43)	30 (25-40)	0.324

ASA-PS: American Society of Anesthesiologists physical status, BMI: body mass index, BP: blood pressure, FEV1: forced expiratory volume in the first second, FVC: forced vital capacity, MEF25-75%: maximal mid expiratory flow rate

Table III. Relationship between presence of major complications and other parameters

	Major complication present	Major complication absent	p
	n (%)	n (%)	
Sex			0.709
Female	11 (7.0)	146 (93.0)	
Male	8 (5.9)	127 (94.1)	
BMI percentile			0.584
Normal	7 (4.7)	142 (95.3)	
Underweight	5 (8.9)	51 (91.1)	
Overweight	2 (10.5)	17 (89.5)	
Obese	1 (8.3)	11 (91.7)	
Comorbidity			0.565
Yes	10 (5.8)	162 (92.4)	
No	9 (7.5)	111 (92.5)	
ASA classification			0.083
1	0 (0.0)	66 (100)	
2	7 (5.5)	120 (94.5)	
3	3 (8.8)	31 (91.2)	
Mallampati score			0.042
1	5 (3.1)	155 (96.9)	
2	5 (10.2)	44 (89.8)	
Anticipated ICU need			<0.001
Yes	9 (16.4)	46 (83.6)	
No	8 (3.5)	221 (96.5)	
Bronchoscopy route			<0.001
Laryngeal mask	13 (4.9)	253 (95.1)	
Nasal	6 (23.1)	20 (76.9)	
Additional dose of anesthetic agent requirement during procedure			0.349
Yes	7 (6.5)	101 (93.5)	
No	6 (3.9)	147 (96.1)	
	Median (Q1-Q3)	Median (Q1-Q3)	
Age (years)	7 (2-13)	10 (6-14)	0.035
Height (cm)	126 (103-158)	143 (122-160)	0.080
Weight (kg)	18 (10-45)	30 (20-46)	0.070
BMI (kg/m^2)	15.22 (13.31-18.99)	16.73 (14.65-19.47)	0.321
Baseline heart rate (bpm)	116 (100-138)	110 (98-126)	0.219
Baseline systolic BP (mmHg)	109 (100-118)	115 (105-123)	0.095
Baseline diastolic BP (mmHg)	59 (51-71)	69 (60-77)	0.018
Baseline respiratory rate (/min)	24 (20-25)	24 (20-28)	0.768
Baseline oxygen saturation (%)	98 (97-99)	99 (97-100)	0.346
FEV1%	80 (49-98)	78 (58-93)	0.959
FVC%	76 (61-90)	67 (56-84)	0.720
MEF25-75%	112 (41-131)	92 (65-112)	0.814
Procedure duration (min)	20 (15-30)	19 (15-20)	0.066
Sedation duration (min)	40 (21-45)	30 (25-40)	0.360

ASA-PS: American Society of Anesthesiologists physical status, BMI: body mass index, BP: blood pressure, FEV1: forced expiratory volume in the first second, FVC: forced vital capacity, MEF25-75: maximal mid expiratory flow rate

In the univariate logistic regression analysis for development of complications, age (odds ratio [OR = 0.902, 95% confidence interval [CI]: 0.846–0.962, p = 0.002), height (OR = 0.979, 95% CI: 0.967–0.991, p = 0.001), anticipated ICU need (OR = 2.199, 95% CI: 1.112–4.350, p = 0.024), nasal route of bronchoscopy (OR = 3.700, 95% CI: 1.593–8.592, p = 0.002), and initial oxygen saturation (OR = 0.866, 95% CI: 0.754–0.994, p = 0.040) were significant predictors.

In the univariate logistic regression analysis for major complication development, age (OR = 0.889, 95% CI: 0.801–0.986, p = 0.026), initial diastolic blood pressure (OR = 0.939, 95% CI: 0.896–0.984, p = 0.009), anticipated ICU need (OR = 5.405, 95% CI: 1.981–14.750, p = 0.001), and nasal route of bronchoscopy (OR = 5.838, 95% CI: 2.004–17.006, p = 0.001) were also significant predictors. The results of the multivariate logistic regression analysis performed to identify independent predictors of bronchoscopy-related complications and major complications are presented in Table IV.

The development of major complications and need for intensive care were statistically significantly more common among patients who

Table IV. Multivariate logistic regression analysis of parameters associated with complications and major complications after bronchoscopy

	p	OR	95% CI
Parameters associated with complications			
Age	0.004	0.905	0.846-0.968
Anticipated ICU need	0.047	2.109	1.010-4.406
Nasal route of bronchoscopy	0.005	4.360	1.569-12.114
Initial oxygen saturation	0.049	0.864	0.745-1.003
Parameters associated with major complications			
Age	0.052	0.896	0.803-1.001
Anticipated ICU need	0.002	5.387	1.891-15.345
Nasal route of bronchoscopy	0.029	4.414	1.160-16.787

CI: confidence interval, ICU: intensive care unit, OR: odds ratio.

Table V. Relationship between anticipated intensive care need and ASA-PS classification and complications after bronchoscopy

	Anticipated ICU need in pre-procedure anesthesia consultation, n (%)		p
	Yes	No	
Need for intensive care			<0.001
Yes	8 (80)	2 (20)	
No	47 (17.2)	227 (82.8)	
Major complication			<0.001
Yes	9 (52.9)	8 (47.1)	
No	46 (17.2)	221 (82.8)	
	ASA-PS classification, n (%)		
	I-II	III-IV	
Complication			0.144
Yes	37 (92.5)	3 (7.5)	
No	156 (83.4)	31 (16.6)	
Major complication			0.173
Yes	7 (70)	3 (30)	
No	186 (85.7)	31 (14.3)	

ASA-PS: American Society of Anesthesiologists physical status, ICU: Intensive care unit.

were recommended for intensive care in the pre-procedure anesthesia consultation notes. There was no significant difference between the ASA-PS I-II and ASA-PS III-IV groups in terms of the presence of complications and the development of major complications (Table V).

Discussion

In our study, we found that FB was generally well tolerated, with the frequency of FB-related complications, major complications, and intensive care needs being 18.8%, 6.5%, and 3.4%, respectively. As in previous studies, there was no bronchoscopy-related mortality.[9] Patient age, height, anticipated ICU need noted in the pre-procedure anesthesia consultation, and pre-procedure oxygen saturation values were predictors for the development of bronchoscopy-related complications. Furthermore, patient age, baseline diastolic blood pressure, anticipated ICU need and bronchoscopy insertion route were predictors of the development of major bronchoscopy-related complications. We observed no association between complications and ASA-PS score, pulmonary function test values, or procedure and sedation duration. In the literature, the reported incidence and severity of FB-related complications are quite inconsistent, varying between 5% and 30%.[1,3,10,11] Carlens et al.[3] stated that this inconsistency may be due to differences in patient selection, complication definitions, and the procedural techniques performed. In their study, they reported intraprocedural minor complications in 7.2%, postprocedural minor complications in 25.8%, major complications in 5.2%, and unplanned intensive care need in 3.1% of their patients. In our study, we used the complications definitions of Carlens et al.[3] and found similar rates of major complications and ICU need.

There are few studies in the literature examining risk factors for bronchoscopy-related complications. These studies indicated that young age was a risk factor with younger age groups more susceptible to desaturation.[12,13] While Schnapf[12] stated in his study that infants aged 6-12 months were more susceptible to desaturation, Carlens et al.[3] found that the major complications were significantly more frequent in patients younger than 2 years compared to those aged 2 years and older (9.2% vs. 3.3%, p=0.009). In addition, they found that additional diagnostic or therapeutic interventional procedures during FB were associated with longer anesthesia duration and an increased risk of serious complications. Similarly, DeBoer et al.[9] found that complications occurred more frequently in patients undergoing multiple procedures on the same day. However, as they did not evaluate anesthesia duration in their study, they could not determine whether this was a contributing risk factor. Consistent with the literature, our findings showed that younger age was associated with bronchoscopy-related complications, while procedure duration and sedation duration were not predictors of complication development. This may be due to the fact that we did not perform many additional interventional procedures during FB. These findings suggest that the risk of complications may depend more on the complexity of the procedure than on its duration or the duration of sedation.

To our knowledge, no previous study has evaluated the relationship between the post-procedure bronchoscopy complications and the pre-procedure anesthesiologist assessment. In our study, we found that the physician's opinion was an important predictor of complications, major complications, and need for intensive care. The physician's anticipation of a potential need for ICU prior to the procedure was associated with a 2.10-fold higher risk of complications and a 5.38-fold higher risk of major complications. We consider this important because it provides a valuable guide for anticipating complications that may develop before FB procedures, particularly in centers that have a limited number of pediatric ICU beds, such as our center.

The use of ASA-PS score as a pre-procedure risk assessment tool in the pediatric population

is controversial because of its inconsistent results.[3,14,15] There are two studies in the literature evaluating ASA-PS scores in pediatric FB. Carlens et al.[3] reported a statistically nonsignificant relationship between high ASA scores and the development of serious complications. In contrast, DeBoer et al.[9] observed fewer unexpected events in the ASA-PS I-II group compared to the ASA-PS III group (18% vs. 55.6%). In our study, ASA-PS score was not a significant predictor of complications or major complications. However, a high Mallampati score was associated with the occurrence of major complications. In a study of obese patients, desaturation occurred more frequently during bronchoscopy in patients with higher Mallampati scores, although this had no effect on bronchoscopy duration or the successful completion of the procedure.[16] To our knowledge, no previous study has evaluated the Mallampati score in relation to bronchoscopy complications in children, and we believe further studies are needed to clarify the role of ASA-PS and Mallampati scoring in risk assessment before pediatric bronchoscopy.

In our study, the most common complication associated with bronchoscopy was hypoxia (11.3%). De Blic et al.[11] in their study on FB complications, reported that complications were detected in 6.9% of patients and the most common complication was hypoxemia, at a rate of 2.7%. Carlens et al.[3] detected hypoxemia in 4.8% of patients during FB. Hypoxemia may occur as a result of depressed respiratory effort due to sedation or from partial or complete airway obstruction by the bronchoscope. It may also occur due to FB-related laryngospasm, bronchospasm, or excessive cough. The condition is usually temporary and reversible.[17] In a study evaluating systemic and cerebral oxygen saturations during FB, systemic desaturation was detected in 18.5% of patients. Male sex, smoking, baseline oxygen saturation, and FEV_1% were identified as the most important factors contributing to FB-related systemic desaturation.[18] In our study, we observed that patients with low pre-procedure saturation values were at higher risk of developing complications, whereas no relationship with sex or pulmonary function parameters were found.

The most common route of bronchoscope insertion in our study was laryngeal mask (91.1%). We excluded patients hospitalized in the ICU because they were more likely to have comorbidities that could impact the rate of bronchoscopy-related complications. Therefore, FB was not performed via an intubation tube and tracheostomy cannula in any patients. There are a limited number of studies in the literature evaluating the effect of the bronchoscopic route on the development of complications. Carlens et al.[3] stated that endotracheal intubation is associated with serious complications. Similarly, Naguib et al.[19] reported a higher rate of hypoxia in cases intubated for FB compared to those using a laryngeal mask. To our knowledge, the literature includes no study comparing the nasal and laryngeal bronchoscopy routes in children. However, Alon et al.[20] reported in a study conducted with adults that desaturation rates were significantly lower in the LMA group compared to the nasal mask group (37% vs 63.4%, p=0.008) and that the use of LMA provided better respiratory support and more stable oxygen saturation. Similarly, in our study, bronchoscopy performed via the nasal route was associated with a 4.36-fold higher risk of complications and a 4.41-fold higher risk of major complications compared to the laryngeal mask approach. Based on this, we believe that the preferential use of an LMA for FB procedure is appropriate in children who do not require dynamic airway evaluation.

This study has several limitations. First, its retrospective design and single-center setting may limit the generalizability of the findings. Additionally, due to the retrospective nature of the study, we were unable to obtain ASA-PS and Mallampati scores for all patients, nor could we evaluate the anesthesiologists' level of experience or the factors influencing their clinical judgment. Furthermore, the relatively low sensitivity values observed in both logistic regression models indicate a limited ability

to correctly identify patients who developed complications or major complications. This is likely attributable to the class imbalance in the outcome variables, as well as the reduction in sample size caused by missing data in some predictor variables. These factors may have affected the overall performance of the models. Future prospective, multicenter studies with more comprehensive data collection and balanced group distributions are needed to validate and improve upon these findings.

Conclusion

Although FB is a fairly safe diagnostic method in pediatric patients, additional caution in terms of possible complications is warranted in young children, when using the nasal route of insertion, or if the patient is evaluated as high-risk in the pre-procedure risk assessment performed by the anesthesiologist. Further studies are needed to evaluate the effect of procedure and sedation times, ASA-PS, and Mallampati score on the development of FB-related complications in children.

Ethical approval

The study was approved by the Ethics Committee of Akdeniz University (Approval no KAEK-545; date 19/7/2023).

Author contribution

The authors confirm contribution to the paper as follows: Study conception and design: AB, AEB, AB², İÖA, BBP; data collection: AB, BBP, AEB; analysis and interpretation of results: all authors; draft manuscript preparation: AB, AEB, AB², İÖA; All authors reviewed the results and approved the final version of the manuscript.

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Conflict of interest

The authors declare that there is no conflict of interest.

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