CHEST

Complications Following Therapeutic Bronchoscopy for Malignant Central Airway Obstruction

Results of the AQuIRE Registry

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BACKGROUND: There are significant variations in how therapeutic bronchoscopy for malignant airway obstruction is performed. Relatively few studies have compared how these approaches affect the incidence of complications.

METHODS: We used the American College of Chest Physicians (CHEST) Quality Improvement Registry, Evaluation, and Education (AQuIRE) program registry to conduct a multicenter study of patients undergoing therapeutic bronchoscopy for malignant central airway obstruction. The primary outcome was the incidence of complications. Secondary outcomes were incidence of bleeding, hypoxemia, respiratory failure, adverse events, escalation in level of care, and 30-day mortality.

RESULTS: Fifteen centers performed 1,115 procedures on 947 patients. There were significant differences among centers in the type of anesthesia (moderate vs deep or general anesthesia, $P < .001$), use of rigid bronchoscopy ($P < .001$), type of ventilation (jet vs volume cycled, $P < .001$), and frequency of stent use ($P < .001$). The overall complication rate was 3.9%, but significant variation was found among centers (range, 0.9%-11.7%; $P = .002$). Risk factors for complications were urgent and emergent procedures, American Society of Anesthesiologists (ASA) score > 3, redo therapeutic bronchoscopy, and moderate sedation. The 30-day mortality was 14.8%; mortality varied among centers (range, 7.7%-20.2%, $P = .02$). Risk factors for 30-day mortality included Zubrod score > 1, ASA score > 3, intrinsic or mixed obstruction, and stent placement.

CONCLUSIONS: Use of moderate sedation and stents varies significantly among centers. These factors are associated with increased complications and 30-day mortality, respectively.

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ABBREVIATIONS: APC = argon plasma coagulation; AQuIRE = American College of Chest Physicians (CHEST) Quality Improvement Registry, Evaluation, and Education Program; ASA = American Society of Anesthesiologists

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Malignant airway obstruction is a serious complication of lung cancer, resulting in dyspnea, decreased functional status, and asphyxiation risk. In addition, pulmonary metastases from other malignancies, including breast, colon, and renal cell cancer, commonly result in malignant airway obstruction.[1] There are three main types of malignant airway obstruction: endobronchial obstruction, extrinsic compression, and mixed pattern. For endobronchial obstruction, ablative techniques that destroy tissue are indicated, including lasers, electrocautery, argon plasma coagulation (APC), photodynamic therapy, microdebriders, and cryotherapy. For extrinsic compression, stents are used to strengthen the bronchial wall and keep the airway open. For mixed patterns, ablation followed by stenting is usually required. Treatment strategies often are multimodal, and variations exist in how physicians perform therapeutic bronchoscopy.

Prior studies of therapeutic bronchoscopy for central airway obstruction[2-12] have included both malignant and benign cases, and most were done retrospectively, although some have focused on malignant disease.[13-18] Reported complication rates are low, but complications and outcomes differ significantly depending on the indication for the procedure (ie, malignant vs benign disease, isolated hemoptysis vs central airway obstruction), and in most studies, significant heterogeneity existed in terms of patient population and indications.[1,4] Many of these studies focused on individual technologies, such as stents, microdebriders, or APC, and most were performed at centers of excellence as part of ongoing research programs. Whether variations in practice patterns affect complication rates is unknown and cannot be answered by single-center studies. In addition, because many previous studies had relatively small sample sizes, formal analysis of rare events like complications has been limited. Whether these results can be generalized to everyday clinical practice is unknown. Additional outcomes data on therapeutic bronchoscopy for malignant central airway obstruction in everyday clinical practice is, therefore, needed to establish benchmarks for quality improvement and clinical effectiveness.

Registries are well suited for this purpose because they provide a more generalizable picture of outcomes and clinical effectiveness. We used the American College of Chest Physicians (CHEST) Quality Improvement Registry, Evaluation, and Education (AQuIRE) program to evaluate therapeutic bronchoscopy for malignant central airway obstruction, focusing on complications and their clinical consequences and 30-day outcomes. The primary objective was to quantify the incidence of and risk factors for complications. The secondary objective was to quantify the incidence and risk factors for bleeding, hypoxemia, respiratory failure, and 30-day mortality and to evaluate the consequences of complications as measured by escalation in level of care and associated adverse events. Data regarding the success rate of therapeutic bronchoscopy and its impact on dyspnea and quality-adjusted survival have been presented separately.[19]

Materials and Methods

Data on patients undergoing therapeutic bronchoscopy from January 2009 to February 2013 were entered into the AQuIRE program.[20] Not all centers started participating at the same time; some centers participated for the entire duration, whereas others participated for ≥1 year. However, participating centers agreed to enter all consecutive patients for the duration of their participation. Institutional review board approval was governed by each site (see e-Appendix 1 for details). The principal investigator for each site was primarily responsible for data quality for that site. Informed consent or a waiver of consent was obtained in accordance with institutional guidelines. Data were entered through the AQuIRE web-based interface using standardized definitions, quality control checks, and protocols as previously described.[21-23]

Patients undergoing therapeutic flexible or rigid bronchoscopy for malignant central airway obstruction were included. Central airway obstruction was defined as occlusion of ≥ 50% of the trachea, mainstem bronchi, bronchus intermedius, or lobar bronchus. Because a registry was used, all clinical decisions, including type of intervention, were left to the discretion of the attending bronchoscopist.

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Information extracted from the AQuIRE program included patient demographics, clinical characteristics, physician and hospital information, sedation information, procedural information, complications, outcomes of complications, adverse events, and 30-day survival. See e-Appendix 1 contains for additional details on definitions. The average number of cases per month was used as a center-level variable in hierarchical models to assess the relationship between center volume and outcomes. Adverse events were defined as events resulting from the complication that extended hospitalization, required intervention to avoid permanent impairment, were life threatening, or caused disability or death.

The primary outcome was procedural morbidity, which was defined as any of the following events within 24 h: bleeding requiring intervention, pneumothorax, refractory hypoxemia defined as oxygen saturation < 90% for > 1 min,[1,22] clinically significant airway injury, hypotension, cardiac arrest or arrhythmia, or unexpected respiratory failure requiring positive pressure ventilation. Secondary outcomes included subsets of complications (ie, bleeding, hypoxemia, respiratory failure), clinical consequences of complications as measured by complications associated with adverse events, need for an escalation in level of care, and death within 30 days. Escalation in level of care, as a measure of resource utilization, was defined as admission to the hospital if the patient was an outpatient, transfer to the ICU if the patient was an inpatient, or death irrespective of whether there was a complication or adverse event (see e-Appendix 1 for additional details). For the outcome of death within 30 days, we analyzed only first therapeutic bronchoscopy cases. The reason is that the probability of death within 30 days of the procedure for patients having more than one procedure would not be independent of each other.

Statistical Analysis

For binary outcomes, the association of the outcome with each covariate was checked by χ^2 or Fisher exact test (for categorical variables) or Wilcoxon-Mann-Whitney two-sample test (for continuous variables) as appropriate. For continuous outcomes, the association of the outcome with each covariate was checked by the *F* test in analysis of variance models (for categorical variables) or *t* test in linear regression models (for continuous variables) as appropriate. Variables with $P < .20$ on univariate analyses were candidates for multivariate models. A backward model selection was applied to retain only variables where $P < .05$. We used hierarchical models to evaluate the impact of center-level variation on homogeneity. Logistic regression using the maximum likelihood approach was used when there were sufficient numbers of events for the outcome; otherwise, logistic regression with the Firth penalized likelihood approach was applied if there were rare events.[24,25] For continuous outcomes, an analysis of covariance model was used. $P < .05$ was considered significant; all tests were two-sided. All statistical analyses were performed with SAS version 9.3 software (SAS Institute Inc).

Results

Fifteen centers with 26 physicians enrolled 947 patients who underwent 1,115 procedures. Patients with lung cancer either had advanced stage disease to begin with or had a recurrence after initial treatment that was unresectable at the time of intervention. Baseline patient and clinical characteristics are shown in Table 1.

Practice Patterns

Significant differences were found in the type of anesthesia used among centers ($P < .001$). Four centers used moderate sedation predominantly (57%-100% of cases). The remaining 11 centers used moderate sedation rarely (range, 0%-15%). There were also significant differences in the use of rigid bronchoscopy ($P < .001$) and type of ventilation used with rigid bronchoscopy ($P < .001$). Four centers predominantly used flexible bronchoscopy without rigid bronchoscopy (86%-100% of cases), five centers predominantly used rigid bronchoscopy (79%-96% of cases), and six centers often used rigid bronchoscopy moderately (48%-69% of cases). When performing rigid bronchoscopy, some centers used jet ventilation, whereas others used volume-cycled ventilation exclusively ($P < .001$). Use of stents varied significantly among centers as well. Among the eight centers with data on ≥ 25 cases (n = 1,052), the proportion of cases in which a stent was placed ranged from 13% to 69% ($P < .001$).

Any Complication

Forty-four patients (3.9%) had complications (Table 2). An escalation in level of care was required in 27 (61%) of these patients. In the four centers that used moderate sedation predominantly, the complication rate was 12.2%; in the 11 centers that used predominantly general anesthesia, the complication rate was 3.0% ($P < .001$). Among the eight centers with data on ≥ 25 cases (n = 1,052), complication rates ranged from 0.9% to 11.7% ($P = .002$). On multivariate analysis, urgent and emergent procedures, American Society of Anesthesiologists (ASA) score > 3, redo therapeutic bronchoscopy, and moderate sedation were associated with increased complication rates.

Complications That Had an Adverse Event

Six patients (0.5%) died secondary to procedural complications (e-Table 1). Four patients had a complication and died within 24 h. Two patients had a complication and died > 24 h after the procedure, but the complication was believed to be contributory. Two other patients died within 24 h but did not have complications. In both cases, death was due to underlying disease progression refractory to treatment. On multivariate analysis, only urgent and emergent procedures and never smoking were associated with procedural complications leading to death (Table 3).

Twenty-four patients (2.2%) had complications as well as an adverse event (Table 4). An escalation in level of care was required in 17 (71%) of these patients. On multivariate analysis, Zubrod score > 1, ASA score > 3, and redo therapeutic bronchoscopy were associated with greater risks of having a complication and adverse event.

TABLE 1] Patient and Clinical Characteristics

Characteristic	Frequency (N = 1,115)
Age, y	62.8 ± 13.3
Baseline Borg score	3.6 ± 2.4
Male sex	620 (55.6)
Inpatient	366 (32.8)
Race	
Nonwhite	202 (18.1)
White	913 (81.9)
Urgency of the procedure	
Elective	767 (68.8)
Emergent	104 (9.3)
Urgent	244 (21.9)
Zubrod score	
≤ 1	469 (42.1)
> 1	646 (57.9)
ASA score	
≤ 3	701 (62.9)
> 3	414 (37.1)
First therapeutic bronchoscopy	
Yes	800 (71.7)
No (redo bronchoscopy, second or later)	315 (28.3)
Comorbidity[a]	
Asthma	55 (4.9)
COPD	339 (30.4)
Cardiovascular disease	566 (50.8)
Diabetes	175 (15.7)
GERD	65 (5.8)
Hematologic malignancy	5 (0.4)
Second primary solid tumor present[b]	7 (0.6)
Renal failure creatinine > 2 or on HD	17 (1.5)
Bleeding risk high due to medications	81 (7.3)
Current or prior tobacco use	872 (78.2)
Cancer related	
Primary lung cancer	800 (71.7)
Time from cancer diagnosis > 75 d	556 (49.9)
Location of disease[a]	
Trachea	255 (22.9)
Left main	416 (37.3)
Right main	459 (41.2)
Bronchus intermedius	268 (24)
Lobar	323 (29)
Any tracheoesophageal fistula	9 (0.8)
Type(s) of obstruction present[a]	
Any endobronchial	549 (49.2)
Any extrinsic	161 (14.4)
Any mixed	485 (43.5)
Procedural variable	
Anesthesia	
Moderate sedation	154 (13.8)
Deep or general	961 (86.2)
Paralysis	
No	283 (25.4)
Yes	832 (74.6)
Type of ventilation	
Volume cycled[c]	714 (64)
Jet	230 (20.6)
Spontaneous	171 (15.3)
Type of bronchoscopy	
Flexible	382 (34.3)
Rigid	733 (65.7)
Ablative technique used	
Any laser used	262 (23.5)
Any electrocautery used	238 (21.3)
Any APC used	393 (35.2)
Any cryotherapy used	89 (8)
Any dilation done	448 (40.2)
Stent placed[a]	
Any stent placed	406 (36.4)
Stent shape[a]	
Any tube stent[d]	331 (29.7)
Any Y stent[e]	85 (7.6)
Stent material	
Any metal stent	298 (26.7)
Any silicone stent	118 (10.6)
Any silicone tube stent	36 (3.2)
Any metal tube stent	295 (26.5)

Data are presented as mean ± SD or No. (%). APC = argon plasma coagulation; ASA = American Society of Anesthesiologists; GERD = gastroesophageal reflux disease; HD = hemodialysis.

[a]Patients could have multiple disease locations, multiple types of obstruction, multiple ablative techniques, and multiple types of stents; therefore, these are not mutually exclusive.

[b]Patients having a second primary cancer present other than the one causing obstruction.

[c]Spontaneous-assist ventilation was classified as volume-cycled ventilation.

[d]If a patient had any non-Y-shaped stent placed, whether metal or silicone, it was considered a tube stent. See e-Appendix 1 for interpretation of ORs related to stent type.

[e]Eighty-three Y stents were silicone, and two were metal.

TABLE 2] Patient and Clinical Characteristics for Any Complications

Characteristic	Univariate Analysis			Multivariate Analysis	
	No Complication (n = 1,071)	Yes Complication (n = 44)	*P* Value	OR (95% CI)[a]	*P* Value
Age, y	62.7 ± 13.2	65.4 ± 16.0	.48[b]	...	...
Race					
Nonwhite	193 (95.5)	9 (4.5)	...	...	...
White	878 (96.2)	35 (3.8)	.68	...	...
Inpatient					
No	724 (96.7)	25 (3.3)	...	...	...
Yes	347 (94.8)	19 (5.2)	.13	...	...
Urgency of the procedure					
Elective	747 (97.4)	20 (2.6)	...	Reference	...
Emergent	96 (92.3)	8 (7.7)	...	2.57 (1.06-6.26)	.038
Urgent	228 (93.4)	16 (6.6)	.002	2.19 (1.09-4.39)	.027
Zubrod score					
≤ 1	458 (97.7)	11 (2.3)	...	...	...
> 1	613 (94.9)	33 (5.1)	.02	...	...
ASA score					
≤ 3	685 (97.7)	16 (2.3)	...	Reference	...
> 3	386 (93.2)	28 (6.8)	.0002	2.58 (1.34-4.99)	.005
First therapeutic bronchoscopy					
No	294 (93.3)	21 (6.7)	...	Reference	...
Yes	777 (97.1)	23 (2.9)	.003	0.36 (0.2-0.67)	.001
Comorbidity					
Asthma					
No	1,019 (96.1)	41 (3.9)	...	...	...
Yes	52 (94.5)	3 (5.5)	.47[c]	...	...
COPD					
No	750 (96.6)	26 (3.4)	...	...	...
Yes	321 (94.7)	18 (5.3)	0.12	...	...
Cardiovascular disease					
No	526 (95.8)	23 (4.2)	...	...	...
Yes	545 (96.3)	21 (3.7)	0.68	...	...
Diabetes					
No	904 (96.2)	36 (3.8)	...	...	...
Yes	167 (95.4)	8 (4.6)	.64	...	...
GERD					
No	1,008 (96)	42 (4)	...	...	...
Yes	63 (96.9)	2 (3.1)	1.0[c]	...	...
Hematologic malignancy					
No	1,068 (96.2)	42 (3.8)	...	...	...
Yes	3 (60)	2 (40)	.01[c]	...	...
Second primary solid tumor					
No	1,064 (96)	44 (4)	...	...	...
Yes	7 (100)	0 (0)	1.0[c]	...	...

(Continued)

TABLE 2] *(continued)*

Characteristic	Univariate Analysis			Multivariate Analysis	
	No Complication (n = 1,071)	Yes Complication (n = 44)	*P* Value	OR (95% CI)[a]	*P* Value
Renal failure creatinine > 2 or on HD					
No	1,054 (96)	44 (4)	…	…	…
Yes	17 (100)	0 (0)	1.0[c]	…	…
Bleeding risk-high medications					
No	993 (96)	41 (4)	…	…	…
Yes	78 (96.3)	3 (3.7)	1.0[c]	…	…
Tobacco use					
Never used	232 (95.5)	11 (4.5)	…	…	…
Current or prior use	839 (96.2)	33 (3.8)	.60	…	…
Cancer related					
Time from cancer diagnosis					
≤ 75 d	541 (96.8)	18 (3.2)	…	…	…
> 75 d	530 (95.3)	26 (4.7)	.21	…	…
Primary lung cancer					
No	306 (97.1)	9 (2.9)	…	…	…
Yes	765 (95.6)	35 (4.4)	.24	…	…
Location of disease					
Trachea					
No	828 (96.3)	32 (3.7)	…	…	…
Yes	243 (95.3)	12 (4.7)	.48	…	…
Left main					
No	679 (97.1)	20 (2.9)	…	…	…
Yes	392 (94.2)	24 (5.8)	.02	…	…
Right main					
No	630 (96)	26 (4)	…	…	…
Yes	441 (96.1)	18 (3.9)	.97	…	…
Bronchus intermedius					
No	814 (96.1)	33 (3.9)	…	…	…
Yes	257 (95.9)	11 (4.1)	.88	…	…
Lobar					
No	762 (96.2)	30 (3.8)	…	…	…
Yes	309 (95.7)	14 (4.3)	.67	…	…
Any tracheoesophageal fistula					
No	1,063 (96.1)	43 (3.9)	…	…	…
Yes	8 (88.9)	1 (11.1)	.30[c]	…	…
Type of obstruction					
Any intrinsic					
No	542 (95.8)	24 (4.2)	…	…	…
Yes	529 (96.4)	20 (3.6)	.61	…	…
Any extrinsic					
No	915 (95.9)	39 (4.1)	…	…	…
Yes	156 (96.9)	5 (3.1)	.67[c]	…	…

(Continued)

TABLE 2] *(continued)*

Characteristic	Univariate Analysis			Multivariate Analysis	
	No Complication (n = 1,071)	Yes Complication (n = 44)	*P* Value	OR (95% CI)[a]	*P* Value
Any mixed					
No	610 (96.8)	20 (3.2)	...	...	...
Yes	461 (95.1)	24 (4.9)	.13	...	...
Procedural variable					
Anesthesia					
Deep or general anesthesia					
Moderate sedation	142 (92.2)	12 (7.8)	...	Reference	...
Deep or general anesthesia	929 (96.7)	32 (3.3)	.008	0.42 (0.21-0.83)	.013
Paralysis					
No	264 (93.3)	19 (6.7)	...	...	...
Yes	807 (97)	25 (3)	.006	...	...
Type of ventilation					
Volume cycled[d]	689 (96.5)	25 (3.5)	...	...	...
Jet	224 (97.4)	6 (2.6)	...	...	...
Spontaneous	158 (92.4)	13 (7.6)	.02	...	...
Type of bronchoscopy					
Flexible	363 (95)	19 (5)	...	...	...
Rigid	708 (96.6)	25 (3.4)	.20	...	...
Any laser used					
No	817 (95.8)	36 (4.2)	...	...	...
Yes	254 (96.9)	8 (3.1)	.40	...	...
Any electrocautery used					
No	845 (96.4)	32 (3.6)	...	...	...
Yes	226 (95)	12 (5)	.33	...	...
Any APC used					
No	692 (95.8)	30 (4.2)	...	...	...
Yes	379 (96.4)	14 (3.6)	.63	...	...
Any cryotherapy used					
No	987 (96.2)	39 (3.8)	...	...	...
Yes	84 (94.4)	5 (5.6)	.39	...	...
Any dilation done					
No	643 (96.4)	24 (3.6)	...	...	...
Yes	428 (95.5)	20 (4.5)	.47	...	...
Stent					
Stent placed					
No	680 (95.9)	29 (4.1)	...	...	...
Yes	391 (96.3)	15 (3.7)	.74	...	...
Metal stent					
No	785 (96.1)	32 (3.9)	...	...	...
Yes	286 (96)	12 (4)	.93	...	...
Silicone tube stent					
No	1,036 (96)	43 (4)	...	...	...

(Continued)

TABLE 2] *(continued)*

Characteristic	Univariate Analysis			Multivariate Analysis	
	No Complication (n = 1,071)	Yes Complication (n = 44)	*P* Value	OR (95% CI)[a]	*P* Value
Yes	35 (97.2)	1 (2.8)	1.0[c]	…	…
Tube stent					
No	753 (96)	31 (4)	…	…	…
Yes	318 (96.1)	13 (3.9)	.98	…	…
Y stent					
No	989 (96)	41 (4)	…	…	…
Yes	82 (96.5)	3 (3.5)	1.0[c]	…	…

Data are presented as mean ± SD or No. (%) unless otherwise indicated. See Table 1 legend for expansion of abbreviations.
[a]Firth penalized likelihood approach used for rare events.
[b]Wilcoxon two-sample test.
[c]Fisher exact test.
[d]Spontaneous-assist ventilation was classified as volume-cycled ventilation.

Death Within 30 Days of Procedure

There were 800 first therapeutic bronchoscopy procedures (Table 5). In the 30 days following bronchoscopy, 119 patients (14.8%) died. Among the seven centers with data on ≥ 25 cases (n = 735), 30-day mortality ranged from 7.7% to 20.2% ($P = .02$). On multivariate analysis, Zubrod score > 1, ASA score > 3, any intrinsic or mixed obstruction, and stent placement were associated with greater risks of death within 30 days of the procedure. Y stents had a higher risk of death (OR, 4.92) than tube stents (OR, 1.72). See e-Appendix 1 for interpretation of the ORs for stents.

Unexpected Escalation in Level of Care

Forty-nine patients (4.4%) had an unexpected escalation in level of care required (e-Table 2). Among the eight centers with data on ≥ 25 cases (n = 1,052), the proportion of patients requiring an unexpected increase in the level of care ranged from 0.5% to 4.2% ($P = .10$). On multivariate analysis, ASA score > 3, gastroesophageal reflux disease, electrocautery use, and dilation were associated with a higher likelihood of requiring escalation in the level of care.

Bleeding Requiring Intervention

Six patients (0.5%) had bleeding requiring intervention (e-Table 3). On multivariate analysis, urgent and emergent procedures, APC use, redo therapeutic bronchoscopy, and never smoking were associated with greater risks of bleeding requiring intervention.

Refractory Hypoxemia

Twenty-two patients (2.0%) had refractory hypoxemia (e-Table 4). On multivariate analysis, redo therapeutic bronchoscopy, tracheoesophageal fistula, and moderate sedation were associated with greater risk of refractory hypoxemia.

Unexpected Respiratory Failure Within 24 Hours

Fifteen patients (1.3%) had unexpected respiratory failure (e-Table 5). On multivariate analysis, nonwhite race, ASA score > 3, diabetes, having a hematologic malignancy, left mainstem disease, and electrocautery use were associated with a greater risk of unexpected respiratory failure (see e-Appendix 1 for a detailed discussion).

Hospital-Level Variation and Complications

We evaluated the impact of center and center-level volume on homogeneity. We did not find evidence of a relationship between average number of cases per month and complication rates, but the analysis was limited because the model did not converge when smaller centers were included. When we used only larger centers, we failed to find evidence of heterogeneity caused by center-level variables. This is not to say that centers had the same outcomes but rather that after evaluating for other covariates, the between-center variance was negligible.

Discussion

In this study, we quantified the risks associated with therapeutic bronchoscopy for malignant central airway obstruction. We found that therapeutic bronchoscopy has a complication rate of 3.9%, with 2.2% of patients experiencing an adverse event and 0.5% of patients dying of complications. We found that moderate sedation, urgent or emergent bronchoscopy, ASA score > 3, and redo bronchoscopy were associated with increased risk of complications. Not all complications resulted in

TABLE 3] Patient and Clinical Characteristics by Complication Resulting in Death

Characteristic	Univariate Analysis			Multivariate Analysis[a]	
	No Complication Resulting in Death (n = 1,109)	Yes Complication Resulting in Death (n = 6)	*P* Value[b]	OR (95% CI)[a]	*P* Value
Age, y (mean)	62.9	59.8	.81[c]	...	...
Race					
Nonwhite	201 (99.5)	1 (0.5)	...	...	...
White	908 (99.5)	5 (0.5)	1.0	...	...
Inpatient					
No	747 (99.7)	2 (0.3)	...	...	...
Yes	362 (98.9)	4 (1.1)	.09	...	...
Urgency of the procedure					
Elective	766 (99.9)	1 (0.1)	...	Reference	...
Emergent	103 (99)	1 (1)	...	8.89 (0.94-83.85)	.06
Urgent	240 (98.4)	4 (1.6)	.01	14.48 (2.3-91.25)	.004
Zubrod score					
≤1	469 (100)	0 (0)	...	...	...
>1	640 (99.1)	6 (0.9)	.04	...	...
ASA score					
≤3	699 (99.7)	2 (0.3)	...	...	...
>3	410 (99)	4 (1)	.20	...	...
First therapeutic bronchoscopy					
No	313 (99.4)	2 (0.6)	...	...	...
Yes	796 (99.5)	4 (0.5)	.67	...	...
Comorbidity					
Asthma					
No	1,054 (99.4)	6 (0.6)	...	...	...
Yes	55 (100)	0 (0)	1.0	...	...
COPD					
No	771 (99.4)	5 (0.6)	...	...	...
Yes	338 (99.7)	1 (0.3)	.67	...	...
Cardiovascular disease					
No	545 (99.3)	4 (0.7)	...	...	...
Yes	564 (99.6)	2 (0.4)	.44	...	...
Diabetes					
No	936 (99.6)	4 (0.4)	...	...	...
Yes	173 (98.9)	2 (1.1)	.24	...	...
GERD					
No	1,044 (99.4)	6 (0.6)	...	...	...
Yes	65 (100)	0 (0)	1.0	...	...
Hematologic malignancy					
No	1,104 (99.5)	6 (0.5)	...	...	...
Yes	5 (100)	0 (0)	1.0	...	...
Second primary solid tumor					
No	1,102 (99.5)	6 (0.5)	...	...	...

(Continued)

TABLE 3] *(continued)*

Characteristic	Univariate Analysis			Multivariate Analysis[a]	
	No Complication Resulting in Death (n = 1,109)	Yes Complication Resulting in Death (n = 6)	*P* Value[b]	OR (95% CI)[a]	*P* Value
Yes	7 (100)	0 (0)	1.0	…	…
Renal failure creatinine > 2 or on HD					
No	1,092 (99.5)	6 (0.5)	…	…	…
Yes	17 (100)	0 (0)	1.0	…	…
Bleeding risk-high medications					
No	1,028 (99.4)	6 (0.6)	…	…	…
Yes	81 (100)	0 (0)	1.0	…	…
Tobacco use					
Never used	239 (98.4)	4 (1.6)	…	Reference	…
Current or prior use	870 (99.8)	2 (0.2)	.02	0.10 (0.02-0.45)	.003
Cancer related					
Time from cancer diagnosis					
≤ 75 d	557 (99.6)	2 (0.4)	…	…	…
> 75 d	552 (99.3)	4 (0.7)	.45	…	…
Primary lung cancer					
No	311 (98.7)	4 (1.3)	…	…	…
Yes	798 (99.8)	2 (0.3)	.056	…	…
Location of disease					
Trachea					
No	857 (99.7)	3 (0.3)	…	…	…
Yes	252 (98.8)	3 (1.2)	.14	…	…
Left main					
No	697 (99.7)	2 (0.3)	…	…	…
Yes	412 (99)	4 (1)	.20	…	…
Right main					
No	655 (99.8)	1 (0.2)	…	…	…
Yes	454 (98.9)	5 (1.1)	.09	…	…
Bronchus intermedius					
No	843 (99.5)	4 (0.5)	…	…	…
Yes	266 (99.3)	2 (0.7)	.63	…	…
Lobar					
No	787 (99.4)	5 (0.6)	…	…	…
Yes	322 (99.7)	1 (0.3)	.68	…	…
Any tracheoesophageal fistula					
No	1,100 (99.5)	6 (0.5)	…	…	…
Yes	9 (100)	0 (0)	1.0	…	…
Type of obstruction					
Any intrinsic					
No	564 (99.6)	2 (0.4)	…	…	…
Yes	545 (99.3)	4 (0.7)	.45	…	…
Any extrinsic					

(Continued)

TABLE 3] *(continued)*

Characteristic	Univariate Analysis			Multivariate Analysis[a]	
	No Complication Resulting in Death (n = 1,109)	Yes Complication Resulting in Death (n = 6)	*P* Value[b]	OR (95% CI)[a]	*P* Value
No	949 (99.5)	5 (0.5)	…	…	…
Yes	160 (99.4)	1 (0.6)	1.0	…	…
Any mixed					
No	626 (99.4)	4 (0.6)	…	…	…
Yes	483 (99.6)	2 (0.4)	.73	…	…
Procedural variable					
Anesthesia					
Moderate sedation	153 (99.4)	1 (0.6)	…	…	…
Deep or general anesthesia	956 (99.5)	5 (0.5)	.59	…	…
Paralysis					
No	282 (99.6)	1 (0.4)	…	…	…
Yes	827 (99.4)	5 (0.6)	1.0	…	…
Type of ventilation					
Volume cycled[d]	711 (99.6)	3 (0.4)	…	…	…
Jet	228 (99.1)	2 (0.9)	…	…	…
Spontaneous	170 (99.4)	1 (0.6)	.60	…	…
Type of bronchoscopy					
Flexible	380 (99.5)	2 (0.5)	…	…	…
Rigid	729 (99.5)	4 (0.5)	1.0	…	…
Any laser used					
No	848 (99.4)	5 (0.6)	…	…	…
Yes	261 (99.6)	1 (0.4)	1.0	…	…
Any electrocautery used					
No	874 (99.7)	3 (0.3)	…	…	…
Yes	235 (98.7)	3 (1.3)	.11	…	…
Any APC used					
No	717 (99.3)	5 (0.7)	…	…	…
Yes	392 (99.7)	1 (0.3)	.67	…	…
Any cryotherapy used					
No	1,020 (99.4)	6 (0.6)	…	…	…
Yes	89 (100)	0 (0)	1.0	…	…
Any dilation done					
No	662 (99.3)	5 (0.7)	…	…	…
Yes	447 (99.8)	1 (0.2)	.41	…	…
Stent					
Stent placed					
No	705 (99.4)	4 (0.6)	…	…	…
Yes	404 (99.5)	2 (0.5)	1.0	…	…
Metal stent					
No	813 (99.5)	4 (0.5)	…	…	…
Yes	296 (99.3)	2 (0.7)	.66	…	…

(Continued)

TABLE 3] *(continued)*

Characteristic	Univariate Analysis			Multivariate Analysis[a]	
	No Complication Resulting in Death (n = 1,109)	Yes Complication Resulting in Death (n = 6)	*P* Value[b]	OR (95% CI)[a]	*P* Value
Silicone tube stent					
No	1,073 (99.4)	6 (0.6)	…	…	…
Yes	36 (100)	0 (0)	1.0	…	…
Tube stent					
No	780 (99.5)	4 (0.5)	…	…	…
Yes	329 (99.4)	2 (0.6)	1.0	…	…
Y stent					
No	1,024 (99.4)	6 (0.6)	…	…	…
Yes	85 (100)	0 (0)	1.0	…	…

Data are presented as No. (%) unless otherwise indicated. See Table 1 legend for expansion of abbreviations.
[a]Firth penalized likelihood approach used for rare events.
[b]Fisher exact test.
[c]Two-sample *t* test.
[d]Spontaneous-assist ventilation was classified as volume-cycled ventilation.

adverse events, but in general, adverse events were more common in patients who had a lower functional status, higher ASA scores, and redo bronchoscopies. We found significant differences among centers in terms of practice patterns, with some centers using predominantly moderate sedation and flexible bronchoscopy and others using general anesthesia and rigid bronchoscopy. Significant differences were also found in stent usage rates. Complication rates and 30-day mortality also varied significantly among centers.

The present study is consistent with and adds to the existing body of evidence regarding therapeutic bronchoscopy complications.[1,2,4,5,16,18,26-30] We focused solely on patients with malignant central airway obstruction because prior work has shown that the magnitude of the effect of risk factors varies based on whether the patient has malignant or benign disease.[1] Many previous studies reporting risk factors for therapeutic bronchoscopy failed to make this distinction. In addition, because of the relatively rare nature of complications and the specialized nature of the procedures involved, many prior studies lacked the statistical power necessary to identify risk factors for rare complications. The present study is among the largest multicenter cohort studies to focus on malignant airway obstruction, and because of this, it allowed us to identify risk factors for specific types of complications that have not been previously reported. We found that redo bronchoscopy and moderate sedation are associated with higher complication rates. Because moderate sedation use varied significantly among centers, this provides an opportunity for improving outcomes in the future. Of note, although the use of neuromuscular paralysis was associated with lower complication rates on univariate analysis (3% vs 6.7%, $P = .006$), after adjustment for the type of anesthesia, the use of paralysis had no impact on complication rates. Similarly, although spontaneous ventilation was associated with higher complication rates than jet or volume-cycled ventilation, after adjustment for the type of anesthesia, the type of ventilation did not affect complication rates. Importantly, the type of anesthesia used is a patient-level variable at some centers (ie, something decided by the bronchoscopist on a case-by-case basis) and a center-level variable at others (eg, in centers where general anesthesia is not readily available for bronchoscopy). The current results suggest that it is important for hospitals to invest the necessary resources to make general anesthesia readily available for therapeutic bronchoscopy.

We also found significant differences among centers in terms of stent use. This may be important because 30-day mortality was higher in patients who had stents placed. However, the association between stents and 30-day mortality may be the result of residual confounding or confounding by indication. Specifically, patients requiring stents may have a higher disease burden, and therefore, the observed decrease in survival might be due to these unaccounted-for factors. This might also explain why Y stents were associated with higher mortality than tube stents. Similarly, physicians may have been more likely to place stents in patients who had few other treatment options and limited life

TABLE 4] Patient and Clinical Characteristics by Any Complication That Also Had an AE

Characteristic	Univariate Analysis			Multivariate Analysis	
	No AE + Complication (n = 1091)	Yes AE + Complication (n = 24)	*P* Value	OR (95% CI)[a]	*P* Value
Age, y (mean)	62.9	61.3	.89[b]	...	...
Race					
Nonwhite	198 (98)	4 (2)	...	...	...
White	893(97.8)	20 (2.2)	1.0[c]	...	...
Inpatient					
No	737 (98.4)	12 (1.6)	...	...	...
Yes	354(96.7)	12 (3.3)	.07	...	...
Urgency of the procedure					
Elective	759 (99)	8 (1)	...	...	...
Emergent	98(94.2)	6 (5.8)	...	...	...
Urgent	234(95.9)	10 (4.1)	.0005	...	...
Zubrod score					
≤1	468 (99.8)	1 (0.2)	...	Reference	...
>1	623 (96.4)	23 (3.6)	.0001	8.66 (1.64-45.6)	.011
ASA score					
≤3	695 (99.1)	6 (0.9)	...	Reference	...
>3	396 (95.7)	18 (4.3)	.0001	3.1 (1.25-7.67)	.015
First therapeutic bronchoscopy					
No	304 (96.5)	11 (3.5)	...	Reference	...
Yes	787 (98.4)	13 (1.6)	.053	0.35 (0.16-0.78)	.01
Comorbidity					
Asthma					
No	1,038 (97.9)	22 (2.1)	...	...	...
Yes	53 (96.4)	2 (3.6)	.33[c]	...	...
COPD					
No	761 (98.1)	15 (1.9)	...	...	...
Yes	330 (97.3)	9 (2.7)	.44	...	...
Cardiovascular disease					
No	535 (97.4)	14 (2.6)	...	...	...
Yes	556 (98.2)	10 (1.8)	.37	...	...
Diabetes					
No	921(98)	19 (2)	...	...	...
Yes	170 (97.1)	5 (2.9)	.57[c]	...	...
GERD					
No	1,027 (97.8)	23 (2.2)	...	...	...
Yes	64 (98.5)	1 (1.5)	1.0[c]	...	...
Hematologic malignancy					
No	1,087 (97.9)	23 (2.1)	...	...	...
Yes	4 (80)	1 (20)	.10[c]	...	...
Second primary solid tumor					
No	1,084 (97.8)	24 (2.2)	...	...	...
Yes	7 (100)	0 (0)	1.0[c]	...	...

(Continued)

TABLE 4] *(continued)*

Characteristic	Univariate Analysis			Multivariate Analysis	
	No AE + Complication (n = 1091)	Yes AE + Complication (n = 24)	*P* Value	OR (95% CI)[a]	*P* Value
Renal failure creatinine > 2 or on HD					
No	1,074 (97.8)	24 (2.2)	…	…	…
Yes	17 (100)	0 (0)	1.0[c]	…	…
Bleeding risk-high medications					
No	1,011 (97.8)	23 (2.2)	…	…	…
Yes	80 (98.8)	1 (1.2)	1.0[c]	…	…
Tobacco use					
Never used	236 (97.1)	7 (2.9)	…	…	…
Current or prior use	855 (98.1)	17 (1.9)	.37	…	…
Cancer related					
Time from cancer diagnosis					
≤ 75 d	550 (98.4)	9 (1.6)	…	…	…
> 75 d	541 (97.3)	15 (2.7)	.21	…	…
Primary lung cancer					
No	308 (97.8)	7 (2.2)	…	…	…
Yes	783 (97.9)	17 (2.1)	.92	…	…
Location of disease					
Trachea					
No	845 (98.3)	15 (1.7)	…	…	…
Yes	246 (96.5)	9 (3.5)	.08	…	…
Left main					
No	689 (98.6)	10 (1.4)	…	…	…
Yes	402 (96.6)	14 (3.4)	.03	…	…
Right main					
No	645 (98.3)	11 (1.7)	…	…	…
Yes	446 (97.2)	13 (2.8)	.19	…	…
Bronchus intermedius					
No	828 (97.8)	19 (2.2)	…	…	…
Yes	263 (98.1)	5 (1.9)	.81[c]	…	…
Lobar					
No	776 (98)	16 (2)	…	…	…
Yes	315 (97.5)	8 (2.5)	.63	…	…
Any tracheoesophageal fistula					
No	1,083 (97.9)	23 (2.1)	…	…	…
Yes	8 (88.9)	1 (11.1)	.18[c]	…	…
Type of obstruction					
Any intrinsic					
No	553 (97.7)	13 (2.3)	…	…	…
Yes	538 (98)	11 (2)	.73	…	…
Any extrinsic					
No	933 (97.8)	21 (2.2)	…	…	…

(Continued)

TABLE 4] *(continued)*

Characteristic	Univariate Analysis			Multivariate Analysis	
	No AE + Complication (n = 1091)	Yes AE + Complication (n = 24)	*P* Value	OR (95% CI)[a]	*P* Value
Yes	158 (98.1)	3 (1.9)	1.0[c]	…	…
Any mixed					
No	618 (98.1)	12 (1.9)	…	…	…
Yes	473 (97.5)	12 (2.5)	.52	…	…
Procedure variable					
Anesthesia					
Moderate sedation	151 (98.1)	3 (1.9)	…	…	…
Deep or general anesthesia	940 (97.8)	21 (2.2)	1.0[c]	…	…
Paralysis					
No	274 (96.8)	9 (3.2)	…	…	…
Yes	817 (98.2)	15 (1.8)	.17	…	…
Type of ventilation					
Volume cycled[d]	696 (97.5)	18 (2.5)	…	…	…
Jet	227 (98.7)	3 (1.3)	…	…	…
Spontaneous	168 (98.2)	3 (1.8)	.57[c]	…	…
Type of bronchoscopy					
Flexible	374 (97.9)	8 (2.1)	…	…	…
Rigid	717 (97.8)	16 (2.2)	.92[c]	…	…
Any laser used					
No	835 (97.9)	18 (2.1)	…	…	…
Yes	256 (97.7)	6 (2.3)	.86	…	…
Any electrocautery used					
No	860 (98.1)	17 (1.9)	…	…	…
Yes	231 (97.1)	7 (2.9)	.34	…	…
Any APC used					
No	704 (97.5)	18 (2.5)	…	…	…
Yes	387 (98.5)	6 (1.5)	.29	…	…
Any cryotherapy used					
No	1,003 (97.8)	23 (2.2)	…	…	…
Yes	88 (98.9)	1 (1.1)	.71[c]	…	…
Any dilation done					
No	657 (98.5)	10 (1.5)	…	…	…
Yes	434 (96.9)	14 (3.1)	.07	…	…
Stent					
Stent placed					
No	695 (98)	14 (2)	…	…	…
Yes	396 (97.5)	10 (2.5)	.59	…	…
Metal stent					
No	801 (98)	16 (2)	…	…	…
Yes	290 (97.3)	8 (2.7)	.46	…	…
Silicone tube stent					
No	1,056 (97.9)	23 (2.1)	…	…	…

(Continued)

TABLE 4] *(continued)*

Characteristic	Univariate Analysis			Multivariate Analysis	
	No AE + Complication (n = 1091)	Yes AE + Complication (n = 24)	*P* Value	OR (95% CI)[a]	*P* Value
Yes	35 (97.2)	1 (2.8)	.40	…	…
Tube stent					
No	769 (98.1)	15 (1.9)	…	…	…
Yes	322 (97.3)	9 (2.7)	.09	…	…
Y stent					
No	1,008 (97.9)	22 (2.1)	…	…	…
Yes	83 (97.6)	2 (2.4)	.70[c]	…	…

Data are presented as No. (%) unless otherwise indicated. AE = adverse event. See Table 1 legend for expansion of other abbreviations.
[a]Firth penalized likelihood approach used for rare events.
[b]Wilcoxon two-sample test; two-sample *t* test.
[c]Fisher exact test.
[d]Spontaneous-assist ventilation was classified as volume-cycled ventilation.

expectancy. However, prior studies have shown that infections are more common in patients undergoing airway stenting and that these infections are associated with a high case fatality rate.[13,14,31] We believe that selectively stenting only patients who really require it is prudent. Although the wide variation in stent use observed among centers (range, 13%-69% of cases; $P < .001$) could be due to differences in the patient populations being treated, it is probable that the present findings reflect at least some degree of variation among centers in terms of stent strategy.

Stent strategy may differ depending on many subtle variations in the underlying indication for airway stenting. In some cases, a stent may be used due to significant residual luminal stenosis not amenable to ablation. In rare cases, stenting may be used to close a fistula. Finally, stents may be used for their barrier effect following successful reopening of the airway with ablative techniques, even though the lumen postablation is > 50% open. In these instances, the physician must make a judgment about whether the risks of recurrent obstruction warrant stenting. It is likely that most of the observed practice variation arises from this last category of patients. Although all patients had at least 50% stenosis prior to bronchoscopy, we did not record the luminal obstruction present at the moment of stenting, only the percentage obstruction, so this outcome analysis can only provide limited insight in this regard. This study cannot answer the question of best stent strategy given the limitations inherent in its design, but the study does highlight the need for future work in this area given the wide variations in practice patterns and the associated increase in 30-day mortality observed with stenting.

To our knowledge, this study is the first to evaluate the impact of hospital-level variables on therapeutic bronchoscopy outcomes. Prior studies of diagnostic bronchoscopy with endobronchial ultrasound-transbronchial needle aspiration found that although little difference exists among hospitals in terms of complication rates, there are significant differences in diagnostic yield, with higher-volume hospitals having higher diagnostic yields.[21,22] In the present study of therapeutic bronchoscopy, the average number of cases per month did not have a significant impact on complication rates. However, the number of centers and the number of patients enrolled from low-volume centers were low relative to the frequency of the events being studied (ie, complications). In addition, the center volumes per month reflected only the number of patients with malignant central airway obstruction. Complex therapeutic bronchoscopies for other indications, such as benign disease, were not considered, but the expertise developed from those procedures would probably be transferrable to malignant cases. Therefore, these findings should be viewed as exploratory because this study lacks the power to reliably detect a relationship between center volume and incidence of complications.

Consistent with prior studies, we found that low performance status was associated with increased 30-day mortality[1,13] and that high ASA scores were associated with more complications and increased health-care resource use.[1,32] Of note, not all prior studies of therapeutic bronchoscopy found a relationship between ASA scores and complications, but this may have been due to sample size limitations and the frequency of complications being relatively low.[12,33,34] In terms of health-care

TABLE 5] Patient and Clinical Characteristics by Death Within 30 Days Among Patients Having Their First Therapeutic Bronchoscopy

	Univariate Analysis			Multivariate Analysis	
Characteristic	Alive in 30 Days (n = 681)	Death in 30 Days (n = 119)	*P* Value	OR (95% CI)	*P* Value
Age, y (mean)	62.6	63.9	.35[a]	...	...
Race					
Nonwhite	125 (84.5)	23 (15.5)	...	...	...
White	556 (85.3)	96 (14.7)	.80	...	...
Inpatient					
No	443 (86.4)	70 (13.6)	...	...	...
Yes	238 (82.9)	49 (17.1)	.19	...	...
Urgency of the procedure					
Elective	469 (88.8)	59 (11.2)	...	...	...
Emergent	66 (81.5)	15 (18.5)	...	...	...
Urgent	146 (76.4)	45 (23.6)	.0001	...	...
Zubrod score					
≤1	287 (92)	25 (8)	...	Reference	...
>1	394 (80.7)	94 (19.3)	<.0001	1.8 (1.07-3.03)	.026
ASA score					
≤3	445 (90.8)	45 (9.2)	...	Reference	...
>3	236 (76.1)	74 (23.9)	<.0001	1.89 (1.21-2.98)	.006
Comorbidity					
Asthma					
No	648 (84.9)	115 (15.1)	...	...	...
Yes	33 (89.2)	4 (10.8)	.64[b]	...	...
COPD					
No	471 (86.9)	71 (13.1)	...	...	...
Yes	210 (81.4)	48 (18.6)	.04	...	...
Cardiovascular disease					
No	337 (86.6)	52 (13.4)	...	...	...
Yes	344 (83.7)	67 (16.3)	.24	...	...
Diabetes					
No	586 (86)	95 (14)	...	...	...
Yes	95 (79.8)	24 (20.2)	.08	...	...
GERD					
No	642 (85.5)	109 (14.5)	...	...	...
Yes	39 (79.6)	10 (20.4)	.26	...	...
Hematologic malignancy					
No	676 (85)	119 (15)	...	...	...
Yes	5 (100)	0 (0)	1.0[b]	...	...
Second primary solid tumor					
No	674 (85)	119 (15)	...	...	...
Yes	7 (100)	0 (0)	.60[b]	...	...
Renal failure creatinine>2 or on HD					
No	670 (85)	118 (15)	...	...	...

(Continued)

TABLE 5] *(continued)*

Characteristic	Univariate Analysis			Multivariate Analysis	
	Alive in 30 Days (n = 681)	Death in 30 Days (n = 119)	*P* Value	OR (95% CI)	*P* Value
Yes	11 (91.7)	1 (8.3)	1.0[b]	...	...
Bleeding risk-high medications					
No	632 (85.1)	111 (14.9)	...	...	...
Yes	49 (86)	8 (14)	.85	...	...
Tobacco use					
Never used	144 (85.2)	25 (14.8)	...	...	...
Current or prior use	537 (85.1)	94 (14.9)	.97	...	...
Cancer related					
Time from cancer diagnosis					
≤75 d	424 (85.8)	70 (14.2)	...	...	...
>75 d	257 (84)	49 (16)	.47	...	...
Primary lung cancer					
No	166 (84.3)	31 (15.7)	...	...	...
Yes	515 (85.4)	88 (14.6)	.69	...	...
Location of disease					
Trachea					
No	542 (86.7)	83 (13.3)	...	...	...
Yes	139 (79.4)	36 (20.6)	.02	...	...
Left main					
No	434 (86.1)	70 (13.9)	...	...	...
Yes	247 (83.4)	49 (16.6)	.31	...	...
Right main					
No	399 (86.9)	60 (13.1)	...	...	...
Yes	282 (82.7)	59 (17.3)	.09	...	...
Bronchus intermedius					
No	523 (85.5)	89 (14.5)	...	...	...
Yes	158 (84)	30 (16)	.63	...	...
Lobar					
No	482 (84.7)	87 (15.3)	...	...	...
Yes	199 (86.1)	32 (13.9)	.60	...	...
Any tracheoesophageal fistula					
No	677 (85.3)	117 (14.7)	...	...	...
Yes	4 (66.7)	2 (33.3)	.22[b]	...	...
Type of obstruction					
Any intrinsic					
No	350 (81.6)	79 (18.4)	...	Reference	...
Yes	331 (89.2)	40 (10.8)	.002	1.93 (1.02-3.63)	.043
Any extrinsic					
No	566 (84.9)	101 (15.1)	...	...	...
Yes	115 (86.5)	18 (13.5)	.63	...	...
Any mixed					
No	400 (90.7)	41 (9.3)	...	Reference	...

(Continued)

TABLE 5] *(continued)*

Characteristic	Univariate Analysis			Multivariate Analysis	
	Alive in 30 Days (n = 681)	Death in 30 Days (n = 119)	*P* Value	OR (95% CI)	*P* Value
Yes	281 (78.3)	78 (21.7)	< .0001	3.48 (1.87-6.48)	< .0001
Procedural variable					
Anesthesia					
Moderate sedation	86 (90.5)	9 (9.5)	...	...	...
Deep or general anesthesia	595 (84.4)	110 (15.6)	.11	...	...
Paralysis					
No	164 (86.3)	26 (13.7)	...	...	...
Yes	517 (84.8)	93 (15.2)	.59	...	...
Type of ventilation					
Volume cycled	449 (83)	92 (17)	...	...	...
Jet	136 (88.3)	18 (11.7)	...	...	...
Spontaneous[c]	96 (91.4)	9 (8.6)	.04	...	...
Type of bronchoscopy					
Flexible	234 (90.7)	24 (9.3)	...	...	...
Rigid	447 (82.5)	95 (17.5)	.002	...	...
Any laser used					
No	506 (84.3)	94 (15.7)	...	...	...
Yes	175 (87.5)	25 (12.5)	.27	...	...
Any electrocautery used					
No	518 (83.1)	105 (16.9)	...	...	...
Yes	163 (92.1)	14 (7.9)	.003	...	...
Any APC used					
No	416 (82.5)	88 (17.5)	...	...	...
Yes	265 (89.5)	31 (10.5)	.007	...	...
Any cryotherapy used					
No	628 (84.2)	118 (15.8)	...	...	...
Yes	53 (98.1)	1 (1.9)	.002[b]	...	...
Any dilation done					
No	411 (87.6)	58 (12.4)	...	...	...
Yes	270 (81.6)	61 (18.4)	.02	...	...
Stent[d]					
Stent placed					
No	428 (90.3)	46 (9.7)	...	Reference	...
Yes	253 (77.6)	73 (22.4)	< .0001	4.92 (2.57-9.42)[d]	< .0001
Metal stent					
No	487 (87.1)	72 (12.9)	...	...	...
Yes	194 (80.5)	47 (19.5)	.01	...	...
Silicone tube stent					
No	658 (85.1)	115 (14.9)	...	...	...
Yes	23 (85.2)	4 (14.8)	1.0[b]	...	...
Tube stent					
No	468 (87.3)	68 (12.7)	...	Reference	...

(Continued)

TABLE 5] *(continued)*

Characteristic	Univariate Analysis			Multivariate Analysis	
	Alive in 30 Days (n = 681)	Death in 30 Days (n = 119)	*P* Value	OR (95% CI)	*P* Value
Yes	213 (80.7)	51 (19.3)	.01	0.35 (0.18-0.66)[d]	.001
Y stent					
No	634 (86.8)	96 (13.2)	…	…	…
Yes	47 (67.1)	23 (32.9)	< .0001	…	…

Data are presented as No. (%) unless otherwise indicated. See Table 1 legend for expansion of abbreviations.
[a]Two-sample *t* test.
[b]Fisher exact test.
[c]Spontaneous-assist ventilation was classified as volume-cycled ventilation.
[d]See e-Appendix 1 for interpretation of ORs for stents.

resource use, higher ASA score was associated with a higher probability of escalation in the level of care postbronchoscopy. Escalation in level of care in the present study does not necessarily reflect harm per se because it did not require a clinical complication to be present. For example, observing a patient overnight after an outpatient procedure would have been considered an escalation in level of care. Rather, escalation in level of care in this context is a measure of resource use. We found that 4.4% of patients required increased health-care resources in the short term following therapeutic bronchoscopy. This is similar to previous reports on Nd:YAG laser in which up to 21% of patients could not be immediately extubated and went to the ICU.[34] This is in contrast to other studies showing that therapeutic bronchoscopy allows deescalation in the level of care.[35] However, those studies focused solely on patients with airway obstruction and acute respiratory failure requiring admission to the ICU prior to bronchoscopy. In such instances, therapeutic bronchoscopy often results in an immediate clinical improvement and deescalation in level of care, albeit perhaps not in the first 24 h; however, that is a very small subset of all patients receiving therapeutic bronchoscopy. The present study provides additional information by assessing the broader population of all patients undergoing therapeutic bronchoscopy for malignant airway obstruction. The data suggest that over the first 24 h, therapeutic bronchoscopy occasionally results in an increase in level of care required, although probably over the long term, quality of life and level of care required improve, consistent with previous studies.[12,35]

Other limitations inherent to the study design are the possibility of residual confounding and confounding by indication. For example, the association between APC use and bleeding is probably not causal, but rather it is a reflection of the fact that when bleeding occurs, an attempt to cauterize the lesion with APC is often made. As with all observational studies, the associations observed may not necessarily be causal. Another limitation is the use of composite outcomes, such as any complication, rather than looking at specific types of complications, such as hypoxemia or bleeding. This can affect the magnitude of the ORs observed and the inferences drawn because a risk factor for one type of complication (eg, hypoxemia) may not be a risk factor for another (eg, bleeding). To address this, we analyzed the data for each major type of complication and reported them separately. However, because complications are rare, it is possible that we failed to identify significant risk factors (ie, β-error) despite the relatively large sample size.

In conclusion, this multicenter registry study of therapeutic bronchoscopy for malignant central airway obstruction is the first to evaluate patient and hospital predictors of complications and adverse events. Complications were relatively rare, occurring in 3.9% of patients, with death occurring in 0.5%. There were significant variations in how therapeutic bronchoscopy was performed. Of the risk factors identified, moderate sedation and stent use were variables most amenable to physician control. Physicians performing therapeutic bronchoscopy for malignant central airway obstruction should consider using general anesthesia rather than moderate sedation or should have general anesthesia readily available during the procedure. Stent placement was associated with increased 30-day mortality, and significant variation in stent use existed among centers. Although this could be due to residual confounding or confounding by indication, careful consideration about whether a stent is truly necessary if the airway lumen can be reopened to ≥ 50% without it is prudent. Future studies should verify these findings and explore the impact of variations in stent strategy on patient outcomes.

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Additional information: The e-Appendix and e-Tables can be found in the Supplemental Materials section of the online article.

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