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The Effect of Major and Minor Complications After Lung Surgery on Length of Stay and Readmission

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Abstract

The effect of post-operative adverse events (AEs) on patient outcomes such as length of stay (LOS) and readmissions to hospital is not completely understood. This study examined the severity of AEs from a high-volume thoracic surgery center and its effect on the patient postoperative LOS and readmissions to hospital. This study includes patients who underwent an elective lung resection between September 2018 and January 2020. The AEs were grouped as no AEs, 1 or more minor AEs, and 1 or more major AEs. The effects of the AEs on patient LOS and readmissions were examined using a survival analysis and logistic regression, respectively, while adjusting for the other demographic or clinical variables. Among 488 patients who underwent lung surgery, (Wedge resection [n = 100], Segmentectomy [n = 51], Lobectomy [n = 310], Bilobectomy [n = 10], or Pneumonectomy [n = 17]) for either primary (n = 440) or secondary (n = 48) lung cancers, 179 (36.7%) patients had no AEs, 264 (54.1%) patients had 1 or more minor AEs, and 45 (9.2%) patients had 1 or more major AEs. Overall, the median of LOS was 3 days which varied significantly between AE groups; 2, 4, and 8 days among the no, minor, and major AE groups, respectively. In addition, type of surgery, renal disease (urinary tract infection [UTI], urinary retention, or acute kidney injury), and ASA (American Society of Anesthesiology) score were significant predictors of LOS. Finally, 58 (11.9%) patients were readmitted. Readmission was significantly associated with AE group ($P = 0.016$). No other variable could significantly predict patient readmission. Overall, postoperative AEs significantly affect the postoperative LOS and readmission rates.

Keywords

minor complications, major complications, length of stay, readmission, lung cancer, surgery

Introduction

Postoperative adverse events (AEs) are defined as any deviation from the normal postoperative course and may lead to increased rates of patient morbidity and mortality (1). Several studies have showed that in-hospital AEs are common in surgical care and that AEs in general surgery were twice as common as in general medical care (2,3). Studies from Canada and other counties showed very high rate of AEs related to surgical procedures (60% and more of all AEs) (4–6). Therefore, post-operative AEs are frequent and significant causes of patient poor health outcomes. In post-surgical care focused studies, AEs occur in the range of 5% to 14% of hospital admissions (7–10). AEs are even more prevalent in thoracic surgery with a reported incidence of 9% to 53.4% (2). It is believed that the majority of these AEs are probably preventable.

The adverse effects of surgical procedures which include both short- and long-term outcomes (morbidity and mortality) (11–14) are concerning to both physicians and patients. However, the effect of the severity of the AEs is not

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completely understood and the effect of postoperative complications on survival is controversial (12–14). It is important to examine the impact of postoperative complications on patients with lung cancer to better manage these patients and prevent suffering. The Clavien-Dido grading system is a simple and reproducible way to grade the postoperative complications or AEs and has been validated for use in surgery to track the severity of patient complications (15).

For early lung cancer, surgical resection is a curative treatment (16) and is the standard approach for non-small cell lung cancer. However, following lung resection, postoperative complications such as hospital-acquired infection, surgical and other invasive AE, urinary retention (≥500 mL), failure in vital signs, drug-related AE, neurological injury, pressure fall, and others are common with a reported incidence of 9.0% to 53.4% (2,17–19). One common result of AEs is increased patient length of stay (LOS) and patients who experienced prolonged LOS demonstrated a higher association with negative patient experience after thoracic surgical procedures (20). Nilsson and others (2) reported over half of the AEs also contributed to prolonged hospital care or readmission, and 4.7% to permanent harm or death. Hence, it is important to understand the association between the prevalence of postoperative AEs in thoracic surgery and their effects on patient outcomes, particularly LOS and readmissions. Also, a better understanding of the relationship between LOS and complications will help providers focus efforts to reduce resource utilization. This study examined the severity of AEs from a high-volume thoracic surgery center and its effect on the patient postoperative LOS or time-to-discharge, as well as readmissions to the hospital. We investigated the incidence and severity of AEs and analyzed the effects of various patient demographics to determine their effect on postoperative AEs.

Methods

Patients

This study included all patients who underwent an elective lung resection between September 2018 and January 2020 in a tertiary hospital (a high-volume thoracic surgery center) in Canada. These patients received Wedge resection, Segmentectomy, Lobectomy, Bilobectomy, or Pneumonectomy for either primary or secondary lung cancers. Lung cancer determined based on the initial imaging of lung malignancy (typically based on computer tomography scans obtained prior to surgical consultation). Patient demographics, comorbidities, complications grade, surgical details, were abstracted from the database and charts. Tumor clinical and pathology staging was categorized according to the 7th Edition of the American Joint Committee on Cancer Staging Manual (21).

Baseline characteristics were compared between patients with and without postoperative complications. Tumor node-metastasis staging was determined based on the eighth edition of the International Association for the Study of Lung Cancer Staging System (22). This study obtained approval from the ethics committee of Hamilton Integrated Research Ethics Board (HiREB #11534). The requirement for patient consent was waived because this was a retrospective cohort study.

Postoperative Complications

Complications were graded based on "The Ottawa Thoracic Morbidity & Mortality System Classifying Thoracic Surgical Complications" Clavien-Dindo classification system (15), which is a validated system to quantitate the effect of AEs. The patients were grouped on whether they had no AEs, 1 or more minor AEs (grade 1 or 2—either no intervention or only pharmacologic intervention respectively) and 1 or more major AEs (grade 3a, 3b, 4a, 4b—surgical/endoscopic/radiological intervention without general anesthesia, with general anesthesia, admission to ICU, and multiorgan failure retrospectively) and Grade 5, death of the patients. Postoperative pulmonary complications were defined, according to a previous report (23) (Lugg 2016), as the occurrence of atelectasis, thoracic empyema, and pneumonia requiring therapeutic intervention, with the following clinical manifestations: consolidations and atelectasis on chest radiography, elevated white blood cell counts >11.2 × 109/L, body temperature >38 °C, purulent sputum, and oxygen saturation <90% on room air. In addition, acute respiratory distress syndrome is not classified independently because we classified postoperative respiratory complications according to the cause of respiratory dysfunction.

Surgical Procedure and Postoperative Follow-up Protocol

All operations were performed under the observation and guidance of the thoracic surgeons of thoracic surgery. The surgical approach (open thoracotomy or video-assisted thoracoscopic surgery or Robotic) was chosen with consideration of the oncological aspects and patients' factors. Follow-up is standard with comprehensive monitoring, AEs surveillance with standard procedures for interventions to AEs.

Statistical Analysis

The results are reported as mean (standard deviation) for continuous variables and count (%) for categorical variables. Clinicopathological factors were evaluated using a χ^2 test or Fisher exact test for categorical variables and Student's *t*-test or Mann–Whitney *U*-test for continuous variables. The effects of the AEs on patient time-to-discharge and readmissions were examined using a flexible parametric survival (Royston-Parmar) model (24,25) and logistic regression, respectively, while adjusting for the effects of age, sex, comorbidities such as COPD, hypertension, diabetes, cardiac disease, Charlton score, and surgery type. Statistical

analysis was conducted using Stata/SE 16.0 (Stata Corporation).

Results

Patients' Characteristics

A total of 494 patients who underwent lung surgery were identified of which majority (98.8%) were alive with 6 in hospital death (1.2%). The 488 alive patients were included in analysis. The types of surgery were—Wedge resection (n = 100), Segmentectomy (n = 51), Lobectomy (n = 310), Bilobectomy (n = 10), or Pneumonectomy (n = 17) for either primary (n = 440) or secondary (n = 48) lung cancers. Postoperative complications were found in 309 (63.3%) patients; 179 (36.7%) patients had no AE, 264 (54.1%) had minor AE, and 45 (9.2%) had major AE. The demographic and clinical characteristics of patients with or without postoperative complications (AEs) are shown in Table 1. The AE and no-AE groups varied significantly with respect to BMI, chronic obstructive pulmonary disease (COPD), cardiac disease, hypertension, and readmissions. The presence of complications also increased the mean LOS compared to patients with no complications (5.56 days vs 2.46 days). Complications did not vary significantly between type of surgery.

Overall, 58 (11.9%) patients were readmitted. Also, readmissions varied significantly ($P = 0.016$) between AE groups (Table 1). Readmitted patients had more major AEs (19.0%) compared to No-readmission group (7.9%). No other variables significantly varied with the patient readmission groups (Table 2).

The average Length of hospital Stay/time-to-discharge and characteristic of patients were also examined (Figure 1). The Median of time-to-discharge was 3 days which varied significantly between AE groups; 2, 4, and 8 days among the no, minor, and major AE groups, respectively (not shown in the table).

Postoperative complications according to the Clavien-Dindo classification (15) are shown in Table 3. The total number of

Table 1. Distribution [n (%)] of Characteristics With or Without Postoperative Complication.

	Minor complication (N = 264)	Major complication (N = 45)	No complication (N = 179)	Total (N = 488)	*P* value
Age, year, mean (SD)	68.0 (8.4)	70.0 (8.9)	66.6 (9.9)	68.2 (9.4)	0.248
Sex					0.339
Male	22 (48.9)	99 (37.5)	78 (43.6)	199 (40.8)	
Female	23 (51.1)	165 (62.5)	101 (56.4)	289 (59.2)	
Smoker					0.433
Current/Former	44 (97.8)	223 (84.5)	149 (83.7)	415 (85.0)	
Never	1 (2.2)	41 (15.5)	29 (16.3)	71 (15.0)	
BMI, kg/m^2 mean (SD)	27.7(7.00)	28.1 (5.8)	29.27 (6.3)	28.7 (6.2)	0.038
Comorbidity					
Diabetes mellitus					0.47
Yes	11 (24.4)	58 (22.0)	35 (19.6)	104 (21.3)	
No	34 (75.6)	159 (60.2)	144 (80.4)	384 (78.3)	
COPD					
Yes	30 (24.4)	105 (39.8)	56 (31.3)	191 (39.1)	0.007
No	34 (75.6)	159 (60.2)	123 (68.7)	297 (60.9)	
Cardiac disease					0.002
Yes	16 (35.6)	78 (29.5)	32 (17.9)	126 (25.8)	
No	29 (64.4)	186 (70.5)	147 (82.1)	362 (74.2)	
Renal disease					0.567
Yes	5 (11.1)	22 (8.3)	13 (7.3)	40 (8.2)	
No	40 (88.9)	242 (91.7)	166 (92.7)	448 (91.8)	
Hypertension					0.001
Yes	23 (51.1)	170 (64.4)	83 (46.4)	276 (56.6)	
No	22 (48.9)	94 (35.6)	96 (53.6)	212 (43.4)	
CVD					0.678
Yes	3 (6.7)	30 (11.4)	17 (9.5)	50 (10.2)	
No	42 (93.3)	234 (88.6)	162 (90.5)	438 (89.8)	
Surgical procedure					0.258
Wedge	7 (15.6)	49 (18.6)	45 (24.6)	101 (20.5)	
Segmentectomy	3 (6.7)	30 (11.4)	18 (10.1)	51 (10.5)	
Lobectomy	32 (71.1)	167 (63.3)	111 (62.0)	309 (63.5)	
Pneumonectomy/Bilobectomy	3 (6.5)	18 (6.7)	6 (3.4)	27 (5.5)	
Readmissions	11 (24.4)	31 (11.8)	16 (8.9)	58 (11.9)	0.016
Length of Stay, mean (SD)	11.4 (11.6)	4.6 (4.0)	2.46 (1.5)	4.0 (3.9)	0.016

Table 2. Characteristics of Patients With or Without Readmissions.

Variables	Readmitted (N = 58), n (%)	No-Readmission (N = 429), n (%)	*P* value
Age, years			0.581
<60	8 (10.26)	70 (89.74)	
60–69	22 (13.92)	136 (86.08)	
> = 70	27 (10.84)	222 (89.16)	
Sex			0.686
Male	25 (12.63)	173 (87.37)	
Female	33 (11.42)	256 (88.58)	
Smoker			0.571
Never	38 (11.21)	301 (88.79)	
Current/Former	19 (13.01)	127 (86.99)	
Alcohol			0.359
No	27 (13.37)	175 (86.63)	
Yes	30 (10.64)	252 (89.36)	
BMI			0.363
Normal	13 (9.49)	124 (90.51)	
Overweight/Obese	43 (12.43)	303 (87.57)	
Comorbidity			
Diabetes mellitus			0.834
No	45 (11.75)	338 (88.25)	
Yes	13 (12.5)	91 (87.50)	
COPD			0.132
No	30 (10.14)	266 (89.86)	
Yes	28 (14.66)	163 (85.34)	
CVD			0.660
No	53 (12.13)	384 (87.87)	
Yes	5 (10)	45 (90)	
Cardiac disease			0.748
No	44 (12.19)	317 (87.81)	
Yes	14 (11.11)	112 (88.89)	
Renal disease			0.529
No	52 (11.63)	395 (88.37)	
Yes	6 (15)	34 (85)	
Hypertension			0.750
No	24 (11.37)	187 (88.63)	
Yes	34 (12.32)	242 (87.68)	
Surgical procedure			0.984
Wedge	13 (13)	87 (87)	
Segmentectomy	6 (12)	44 (88)	
Lobectomy	36 (11.61)	274 (88.39)	
Pneumonectomy/ Bilobectomy	3 (11.11)	24 (88.09)	
Complications			0.016
No	16 (27.59)	163 (38.00)	
Minor	31 (53.44)	232 (54.07)	
Major	11 (18.97)	34 (7.93)	

postoperative complications was 748 (372 grade 1, 314 grade 2, 51 grade 3, and 11 grade 4 complications). In total, 198 patients had 2 or more complications. The most common complication requiring intervention (grade 2 +) was urinary retention (80/488, 16.4%), followed by prolonged air leak (52/488, 10.7%), and arrhythmias (33/488, 6.8%). There were 308 postoperative pulmonary and/or pleural complications (41.2% of complications). The most common major complication (grade 3 +) was mucus plugging (13/62, 21% of major complications). The most common cause of admission to the ICU was respiratory failure (4/11, 36.4% of ICU admissions). Respiratory failure was also the most common cause of exclusion from the study due to death (5/6, 83.0% of deaths) (Table 3).

Modeling Time-to-Discharge

The final survival model for time-to-discharge (LOS) included AE (with major AE as the reference group), type of surgery, renal disease including UTI, urinary retention, or acute kidney injury (yes, no) and ASA (American Society of Anesthesiology) score. The adjusted likelihood of discharge for patients in the no-complication group was more than 10 times compared to patients in the major complication group (HR = 10.57; 95%CI: 5.66-19.72). This likelihood was 3.88 (95%CI: 2.11-7.16) for the patients in the minor-complication group compared to major complication group. The estimated discharge rates (per 100 person-day) based on AE and type of surgery are depicted in Figure 1. As can be seen, the no-complication group had much higher discharge rate compared to minor and major complication groups. Also, patients who underwent wedge resection has much higher discharge rate compared to the other types of surgery. The discharge rate for all types of resection reached at the highest level 3 days after surgery and decreased afterwards.

Modeling Readmission

The final model for readmission only included AE with no-complication as the reference group. There was no association between readmission and the other variables. There was no difference between minor complication and no-complication on the rate of readmission (OR = 1.36; 95%CI: 0.72-2.57). However, the chance of readmission was significantly higher in the major AE group compared to no-complication group (OR = 3.30; 95%CI: 1.41-7.73) (Table 4).

Discussion

In this study 6 of 10 patients had at least 1 postoperative complication and 6 out of 10 had multiple complications. Total number of postoperative complications was 748, that means, about 8 of 10 of which were major complications. Urinary retention, prolonged air leak, and arrythmias were the most common complications. Mucus plugging was the most common major complication and ICU admission was mostly for respiratory failure.

It was found that postoperative AEs significantly affect the postoperative LOS and readmission rates which was not surprising. Few other studies also reported the same findings (26,27). However, the major AEs increased the LOS and readmission rate more than minor AEs. The median LOS was 3 days, which compares to literature (28) (Wright et al. 2008). However, patients with no complications had a

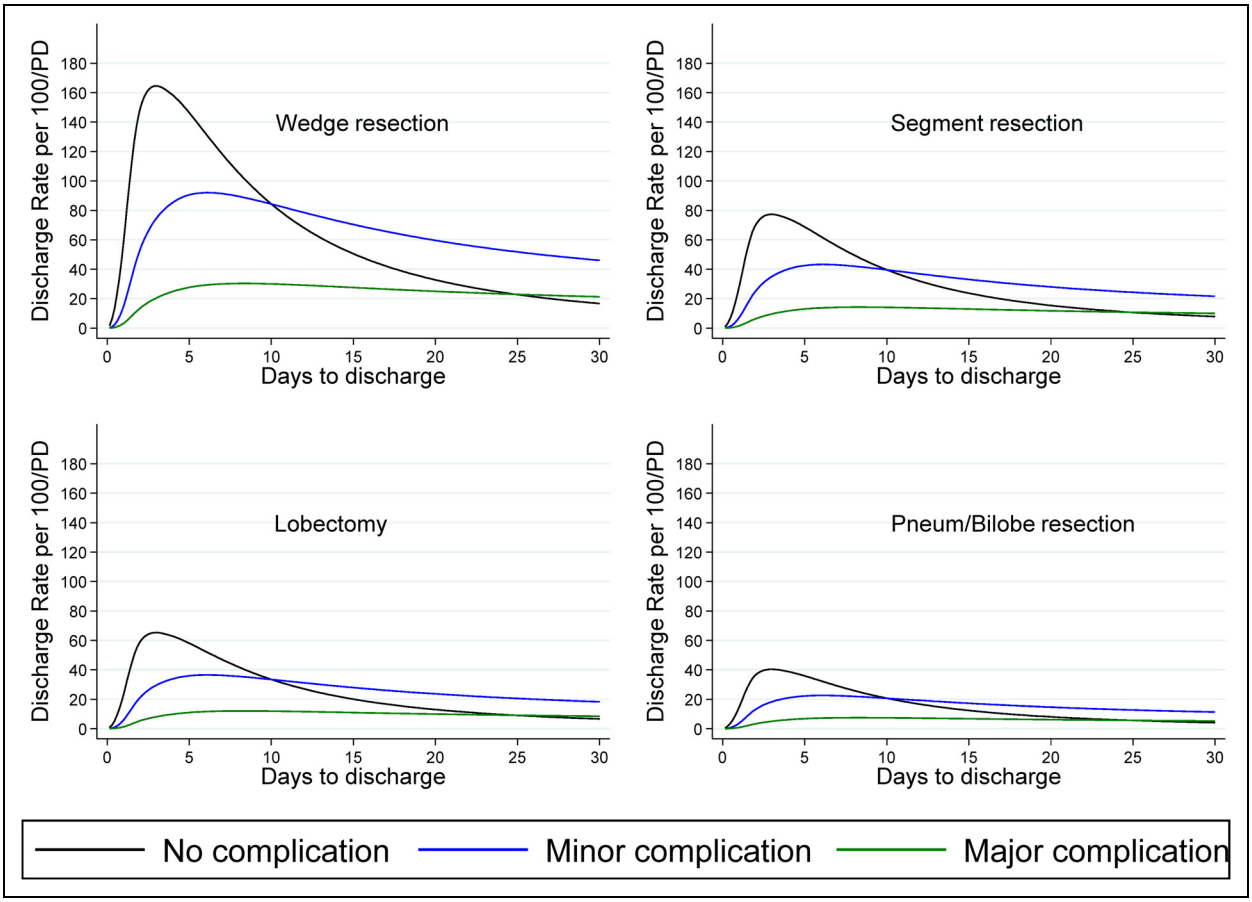

Figure 1. Discharge rate from time of resection (per 100 person-day).

median LOS 2 days, minor complications a median LOS of 4 days, and major complications a median LOS of 8 days. Of the 58 patients who were readmitted, 44 (72.4%) had a complication postoperatively of which 11 (19.0%) were major complications while of the 429 patients who were not readmitted, only 266 (62.0%) had a complication of which 34 (7.9%) were major complications. It is possible that postoperative AEs increase the LOS because the patients had to remain in hospital to receive treatment for the complications, and because minor complications are generally resolved faster that major complications. Patients who had a postoperative complication are more likely to be readmitted, possibly due to the fact that the complication can recur at home (29) or because they are in poorer health due to the previous complication or other reasons (29). McDevitt and others (29) reported that among 1284 patients who underwent resection, emergency readmission was significantly more likely in patients with 2 + comorbidities and had Stage III disease or higher. The main reasons for emergency readmission were also pulmonary complications (29%), cardio/cerebrovascular events (21%), or infection (20%). Current study also found that patients with COPD, hypertension, and cardiac disease were more likely to have complications than patients without which is congruent with other studies (30,31). Oddly, BMI was higher in patients with no complications. Obesity is generally believed to be a risk factor for the development of postoperative complications, however recent studies show that, except for wound infections, complication rates are not increased in this group of patients (32–35). Whereas Tjeertes and others (36) found that obesity is a significant risk factor for surgical site infection, more surgical blood loss and a longer operation time and ultimately LOS. We did not find a significant difference in complication rates between type of surgery. However, a significant difference in the mean LOS and complication rates was reported by freedman in Lobectomy patients (37).

In addition to postoperative AEs—type of surgery, renal disease, and ASA Score were also able to predict time to discharge. Type of surgery can predict time to discharge likely due to the fact that more minor surgeries such as wedges have a shorter recovery time and less chance of complications than more major surgeries such as pneumonectomies' (38). Renal disease can predict time to discharge as it is a well-known risk factor for complications after surgery (39). ASA status is a way to grade patients overall health (40) and as such it makes sense that ASA is able to predict how long a patient is admitted to the hospital as shown by Park (41). We found no variable besides postoperative AEs that effected readmission.

Table 3. Common and Major Postoperative Complications Classified According to Clavien-Dindo.

Postoperative complications	Grade 2	Grade 3	Grade 4	Total number	Proportion of complications (%)
Pulmonary and pleural space					
Pneumonia	18	2	1	21	5.58
Mucus plug	2	13	0	15	3.99
ARDS/respiratory failure	5	0	4	9	2.39
Home on oxygen	18	0	0	18	4.79
Pneumothorax	4	6	1	11	2.92
Hemothorax	1	1	1	3	0.80
Chylothorax	2	1	0	3	0.80
Effusion	3	2	0	5	1.33
Empyema	2	1	0	3	0.80
Prolonged air leak	46	6	0	52	13.83
Subcutaneous emphysema	10	8	0	18	4.79
Cardiovascular					
Arrhythmia	33	0	0	33	8.78
MINS	14	0	0	14	3.72
Renal					
UTI	2	0	1	3	0.80
Urinary retention	76	4	0	80	21.28
AKI	8	0	1	9	2.39
Others related to operative procedure					
Obstruction/ileus	1	1	0	2	0.53
Confusion/delirium	5	0	0	5	1.33
CVA/TIA	0	1	0	1	0.27
Hematoma	1	0	1	2	0.53
Wound infection	2	0	0	2	0.53
Others[a]	61	5	1	67	17.82
Sum	314	51	11	376	100

[a]1 case grade 2 atelectasis. 1 case grade 2 shortness of breath. 2 cases grade 2 MI. 1 case grade 2 ischemia. 3 cases grade 2 PE. 1 case grade 2 DVT. 2 cases grade 2 pericarditis. 4 cases grade 2 hypertension. 1 case grade 3a heart block. 1 case grade 2 post cardiac injury syndrome. 18 cases grade 2 anemia requiring transfusion. 4 cases grade 2 hypotension. 1 case grade 2 hematuria. 1 case grade 2 renal insufficiency. 2 cases grade 2 renal failure. 2 cases grade 2 urosepsis. 1 case grade 2, 1 case grade 4a hyponatremia. 4 cases grade 2 nausea/vomiting. 1 case grade 2 GI bleed. 1 case grade 3a decreased level of consciousness. 1 case grade 2 dehiscence. 1 case grade 2, 3 cases grade 3a postop pain. 2 cases grade 2 anxiety attack. 1 case grade 2 headache. 2 cases grade 2 weakness NYD. 1 case grade 2 bleeding. 3 cases grade 2 sepsis.

Table 4. Predictors of Readmission Based on Different Variables.

Variable	OR (95% CI)	*P* value
Adverse effect		
No-complication	Reference group	—
Minor complication	1.36 (0.72, 2.57)	0.342
Major complication	3.30 (1.41, 7.73)	0.006

Study limitations: This study only includes data from 1 institution, therefore, the results may not be generalizable. Complications alter the treatment of the patient compared to those who do not have complications. Small sample size is another limitation. Sicker patients more likely to get complications and also more likely to stay in hospital longer and to get readmitted (42). This study focused on all the postoperative complications; however, it remains important to realize that patients experienced a long list of complications which are not shown in detail in Table 3. Another limitation of this study is many factors can play a role in the occurrence of postoperative AEs which cannot be identified because of the nature of the study.

In case of observational studies as always, confounding is a concern. However, several measures were taken to minimize the impact of possible confounding, including control for a wide range of well-established prognostic factors (see in modeling). The findings of this study, the effect of postoperative complications on patients with lung cancer would help better manage patients and may prevent discomfort.

Conclusions

In conclusion, major complications such as urinary retention, prolonged air leak, and arrythmias were the most common complications (Table 3). Also, mucus plugging was the most common major complication. Postoperative AEs significantly affected the postoperative LOS and readmission rates. The major AEs increased the LOS and readmission rate more than minor AEs.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical Statement

This study was approved by the ethics committee of Hamilton Integrated Research Ethics Board (HiREB) (#11534 date 28/09/2020). The requirement for patient consent was waived because this was a retrospective cohort study.

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