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INCIDENCE OF AND RISK FACTORS FOR PULMONARY COMPLICATIONS AFTER NON-THORACIC SURGERY

Finlay A. McAlister,[1] MD MSc

Kimberly Bertsch,[1] BScN MSc

Jeremy Man,[1] BMSc

John Bradley,[1] MD

Michael Jacka,[2] MD MSc

From: The Division of [1]General Internal Medicine and [2]The Department of Anesthesiology and Critical Care Medicine, University of Alberta, Edmonton, Canada.

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Address for Correspondence:

Dr. F. McAlister
2E3.24 WMC, University of Alberta Hospital
8440 112 Street
Edmonton, Alberta
Canada T6G 2R7
Tele: (780) 407-1657
Fax: (780) 407-2680
e-mail: Finlay.McAlister@ualberta.ca

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ABSTRACT

The prediction of post-operative pulmonary complications is an under-investigated field. We conducted a prospective cohort study (with postoperative pulmonary complications ascertained by an investigator blinded to perioperative variables) to determine the risk factors for pulmonary complications after elective non-thoracic surgery. Of 1055 consecutive patients attending the Pre-Admission Clinic of a university hospital (mean age 55 years, 50% men, 15% with history of obstructive airways disease), 28 (2.7%) suffered a postoperative pulmonary complication within 7 days of surgery: 13 patients developed respiratory failure requiring ventilatory support, 9 pneumonia, 5 atelectasis requiring bronchoscopic intervention, and 1 pneumothorax requiring intervention. Mean lengths of stay were substantially prolonged for those patients who developed pulmonary complications within 7 days of surgery: 27.9 days versus 4.5 days, $p=0.006$. Eight variables were statistically significantly associated with pulmonary complications on bivariate analyses. Multivariate analyses revealed that 4 were independently associated with increased risk of pulmonary complications: age (OR 5.9 for age $\geq$ 65 years, $p<0.001$), positive cough test (OR 3.8, $p=0.01$), perioperative nasogastric tube (OR 7.7, $p<0.001$), and duration of anesthesia (OR 3.3 for operations lasting at least 2.5 hours, $p=0.008$). Thus, several perioperative factors predict an increased risk for pulmonary complications after elective non-thoracic surgery.

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Pulmonary complications after non-thoracic surgery are more frequent than cardiac complications and are associated with greater increases in length of stay.[1,2] However, our knowledge of the perioperative factors which increase the risk of these complications is imperfect.[3]

Only 8 small studies (averaging 207 patients and 16 outcomes per study) have compared the preoperative evaluation and postoperative pulmonary outcomes in an independent and blind fashion for patients undergoing non-thoracic surgery.[4-11] These studies were limited by non-representative samples (only 2 enrolled consecutive patients undergoing a wide variety of non-thoracic surgeries, and one of these was restricted to patients referred to internists for preoperative assessment) and reported conflicting results: while 20 variables were found to be significantly associated with postoperative pulmonary complications in at least one of these studies, only 7 were significant in more than one study.[10,11] Further, the definitions of postoperative pulmonary complications in these studies were often not explicit and the incidence ranged between 2% and 19%: some studies included clinically insignificant complications (such as asymptomatic changes in pulmonary function tests or oximetry) while others restricted their analyses to outcomes such as respiratory failure or pneumonia. These limitations may distort associations between baseline variables and outcomes, calling into question the results of most of these studies.[12]

While risk prediction equations for postoperative respiratory failure and pneumonia derived from the Veterans Affairs National Surgical Quality

Improvement Program (NSQIP) permit general estimates of risk in patients undergoing a variety of surgical procedures,[13,14] they do not include data from the physical examination or pulmonary function tests which are commonly employed by clinicians to assist in risk prediction prior to surgery. Moreover, the generalizability of these risk prediction equations to the predominantly healthy patients undergoing elective non-thoracic surgery is uncertain since the NSQIP cohort was 97% male, had a high burden of comorbidities, and almost one third of the surgeries were intra-thoracic or emergent.

Thus, in order to identify risk factors for postoperative pulmonary complications in patients undergoing elective non-thoracic surgical procedures, we designed this study and incorporated all of the methodologic features recommended to reduce bias in an observational prognosis or diagnosis study.[12]

METHODS (754 words)

This prospective cohort study was conducted in the Pre-Admission Clinic at the University of Alberta Hospital and none of the patients from our earlier study[11] were included in this study. The University of Alberta Hospital is a tertiary care, university hospital with 677 adult beds and an anaesthesiologist-run Pre-Admission Clinic which processes approximately 9500 patients scheduled for elective non-thoracic surgery per year (a nurse and an anaesthesiologist see all patients scheduled for elective surgery, including day surgery cases [16% of the total in 2002], and internists are consulted at the discretion of the anaesthesiologist). In an unrelated study conducted in our Pre-Admission Clinic, 13% of attendees were deemed by the anaesthesiologist to be ASA class 1, 53% ASA class 2, 33% ASA class 3, and 2% ASA class 4 and 8% of patients received a preoperative internal medicine consult; of the patients undergoing non-thoracic surgery, 31% underwent orthopaedic limb surgery, 29% general surgery procedures, 13% neurosurgical procedures, and 22% other non-thoracic procedures (including urologic, plastics, Ear Nose and Throat, and ophthalmologic).(Dr. B. Finegan, personal communication, September 2004). We approached consecutive adults who were scheduled to undergo elective non-thoracic surgery with planned postoperative admission to a regular ward- 98% of those approached agreed to participate. We excluded patients who were hospitalized or mechanically ventilated at the time of preoperative assessment, patients who were planned for admission to the ICU postoperatively for monitoring, or those patients with a history of sleep apnea requiring CPAP, neuromuscular disease, or medical problems that precluded their participation (such as cognitive impairment).

One investigator performed a standardized history, physical examination, and spirometry on study participants preoperatively with attention to those variables outlined in Tables 1 and 2 (these variables were chosen *a priori* because 20 have been reported to predict pulmonary complications in at least one previous study and 5 were felt to have sufficient face validity that they merited evaluation despite earlier negative studies).[3-11] The method for performing each of the physical examination maneuvers is provided in the Online data supplement; for example, the cough test is performed by having the patient take a deep inspiration and cough once, and a positive test is defined as recurrent coughing after the first cough.

Postoperatively, a second investigator (a physician blinded to the perioperative evaluation and not involved in the patient's ongoing care) collected data on the occurrence of a symptomatic and clinically significant postoperative pulmonary complication within the first 7 postoperative days through review of chart, laboratory, and radiology data. These included: (1) respiratory failure requiring mechanical ventilation, (2) pneumonia, (3) atelectasis requiring bronchoscopic intervention, and (4) pneumothorax or pleural effusion requiring percutaneous intervention. Only the first of these complications occurring in any one patient was used in the analyses. Perioperative laboratory tests (such as chest radiographs or arterial blood gases) and management were left to the discretion of the attending physicians caring for these patients- prophylactic measures (such as incentive spirometry) are not routinely used in our hospital to prevent postoperative pulmonary complications. Data on length of stay was also collected. Errors in outcome ascertainment were minimized through the use of detailed definitions established *a priori* and by reabstraction of a random sample of the postoperative charts to confirm outcomes by an independent investigator.

To evaluate the relationship between the perioperative variables and outcomes, we used the Chi-square test or Fisher's exact test for dichotomous variables and the t-test for continuous variables. As we planned to conduct multiple comparisons, we a priori adjusted the p value for significance to $P \leq 0.01$ using the Bonferroni correction for these analyses. After confirming normality, the continuous variables (age, pack years of smoking, body mass index, FEV1, FVC, and duration of anesthesia) were dichotomized using cut-points previously described in the literature and confirmed by receiver operating curve analyses.[3-11] Multivariate logistic regression analyses were performed incorporating all factors with $p<0.20$ on bivariate analyses and a prevalence of at least 1%, as well as other variables felt to be potentially clinically important, using the backward stepwise selection technique and accepting statistical significance at $p<0.05$. Continuous variables in the model were tested for linearity and replaced with a dichotomized variable if not linear. Further, as including more than one spirometry variable would create problems with collinearity, we selected FEV_1 for the model. All analyses were performed using SPSS statistical software (version 11; SPSS, Chicago, IL).

Additional details on the variables collected (including how to perform the physical examination maneuvers and the types of surgeries included), the outcomes sought, and data analysis are provided in an online data supplement.

RESULTS

We enrolled 1055 consecutive patients who attended the University of Alberta Pre-Admission Clinic between June 2001 and October 2003. The mean age was 55 years, 531 (50%) were men, and 28 (2.7%) suffered a pulmonary complication within 7 days of surgery: 13 developed respiratory failure requiring ventilatory support, 9 postoperative pneumonia, 5 atelectasis requiring bronchoscopic intervention, 1 pneumothorax requiring intervention. One of the patients who developed postoperative pneumonia subsequently died. Lengths of stay were substantially prolonged for those patients who developed pulmonary complications within 7 days of surgery: mean 27.9 days versus 4.5 days, p=0.006.

Only 92 (9%) study participants underwent upper abdominal surgery; the most frequent types of surgery were lower abdominal/inguinal hernia surgery (n=321, 30%) and orthopedic limb surgery (n=238, 23%). The 91 patients (9%) who were referred for preoperative medicine consults were no more (or less) likely to have postoperative pulmonary complications than those patients not referred (Odds Ratio [OR] 1.22, 95% confidence interval [CI] 0.36 to 4.14).

The results of bivariate analyses are outlined in Tables 1 and 2. Of the variables reported to be associated with pulmonary complications in more than one previous study, only reduced exercise capacity was not significant in our study (OR 0.88, 95% CI 0.26 to 0.96). Even after excluding patients going for orthopedic lower limb surgery (in whom non-cardiopulmonary reasons likely influenced exercise capacity), reduced exercise capacity was not associated with pulmonary complications (OR 1.61, 95% CI 0.47 to 5.51). In addition to the definition of a current smoker we employed (within 2 weeks of surgery), we also examined whether the NSQIP definition of current smoker (within 12 months of surgery) was associated with pulmonary outcomes- it was not (OR 1.14, 95% CI 0.50-2.63).

Only 11 of the patients in this cohort had a preoperative arterial blood gas ordered by their attending physician and although one patient had a PCO2 $\geq$ 45 mm Hg, none of these patients developed pulmonary complications after surgery.

Preoperative chest radiographs were ordered for 135 patients, but these patients were not more likely to have an adverse pulmonary event after surgery (OR 1.14, 95% CI 0.39 to 3.34).

The multivariate regression analysis identified 4 variables which were independently associated with an increased risk of postoperative pulmonary complications: age (OR 5.9 for age $\geq$ 65 years, p<0.001), positive cough test (OR 3.8, p=0.01), perioperative nasogastric tube (OR 7.7, p<0.001), and duration of anesthesia (OR 3.3 for operations lasting at least 2.5 hours, p=0.008). The model demonstrates good discrimination and calibration with a C-statistic of 0.875 and a Hosmer-Lemeshow goodness-of-fit statistic of 6.9 (p=0.55).

DISCUSSION

In summary, we confirmed that 8 of the 20 previously reported perioperative variables are associated with postoperative pulmonary complications: age, pack years smoked, positive cough test, FEV1, FEV1/FVC ratio, duration of anesthesia, upper abdominal incision, and perioperative placement of nasogastric tube. However, only 4 of these variables were independently associated with increased risk after multivariate analysis: age, positive cough test, perioperative nasogastric tube, and duration of anesthesia.

Our findings are consistent with the published NSQIP risk prediction equations. For example, we found significant associations between age, history of chronic obstructive pulmonary disease, or upper abdominal incisions and postoperative pulmonary complications which were of similar magnitude to those reported by Arozullah et al.[13,14] However, we were able to go beyond their prediction equations to demonstrate that simple bedside manouvers easily incorporated into the clinical examination (such as the cough test and forced expiratory time) are also useful in identifying patients at increased risk for pulmonary complications.

Our findings are congruent with previous studies employing blinded comparisons between preoperative clinical assessment and postoperative outcomes, but go beyond simply confirming already known associations. For example, several studies have shown that smoking history correlates with pulmonary complications;[6,13,14] however, we were able to quantify the degree of risk conferred by smoking (a 191% increase in risk for a 40 pack year smoker versus a non-smoker). Further, we were able to extend previous reports[8,11] that “abnormal preoperative physical examination” predicts pulmonary complications by clearly defining which elements of the clinical examination are most predictive (cough test and forced expiratory time). Moreover, this study refutes case-control studies[3,15] that failed to find an association between preoperative spirometry values and postoperative pulmonary events and confirms the data from our earlier study (collected in a different sample of patients) that FEV1 < 1L is an adverse prognostic factor (OR 6.5 in this study versus 7.9 in our study of 272 patients referred to general internists).[11] Similarly, the odds ratios we found for other elements of the preoperative evaluation are consistent with those reported in earlier studies: history of chronic obstructive pulmonary disease (OR 3.2 in this study versus 4.5 and 4.2 in other studies),[9,11] and chronic productive cough (OR 2.7 in our study versus 2.2 and

1.9 in earlier studies).[10,11] Similar to 4 previous studies,[5,6,10,11] we did not find an association between general anesthesia and risk of pulmonary complications. However, we are the third study to show that placement of a nasogastric tube perioperatively substantially increases the risk of pulmonary complications, even after adjusting for all other covariates (including site of operation and duration of anesthesia).[9,10] Taken together with randomized trials demonstrating increased risks of atelectasis and pneumonia with routine versus selective nasogastric decompression,[16,17] we believe our data supports calls to minimize the use of routine perioperative nasogastric intubation unless judged to be necessary on clinical grounds.

Although we fulfilled the criteria cited for a high quality prognostic study (we collected perioperative data for a consecutive sample of patients undergoing a full spectrum of elective non-thoracic surgeries, with ascertainment of postoperative outcomes by an independent investigator blinded to the perioperative variables), our study does have some limitations. First, this prediction model has not been validated in an independent data set, although as detailed above many of our findings are consistent with other studies. Second, we relied on patient self-report for smoking history and exercise capacity and some may question the accuracy of patient recall. However, there seems little reason to believe that patients in this study would systematically over/underestimate their smoking history or exercise capacity compared to patients seen in usual practice and, as such, this “limitation” has little bearing on our findings about which elements of the history reported by patients are useful in identifying those who are at increased risk. However, we would suggest that clinicians clarify with patients whether their reduced exercise capacity is truly from exertional dyspnea rather than limb/joint symptoms. Third, we limited our postoperative surveillance to complications which were irrefutably pulmonary and did not include other complications such as pulmonary emboli or heart failure which we felt could have multifactorial etiologies. Finally, it should be emphasized that our study was conducted with patients scheduled to undergo elective non-thoracic surgery and who attended a Pre-Admission Clinic- our results should not be extrapolated to other patient populations (such as hospitalized patients awaiting emergent cardiac surgery) likely to differ substantially from the relatively healthy patients in our cohort.

Of the approximately 45 million North Americans who will undergo non-thoracic surgery in the next year, over 1 million will experience a postoperative pulmonary complication. The occurrence of these complications has enormous implications for the patient and the health care system. The first step in reducing postoperative pulmonary complications is to identify which patients are at increased risk. By doing so, we can more closely follow high risk patients and target future intervention studies towards those patients most likely to benefit. We have demonstrated that certain perioperative factors can be used to identify patients awaiting elective non-thoracic surgery at increased risk for postoperative pulmonary complications.

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References:

1. Lawrence VA, Hilsenbeck SG, Mulrow CD, Dhanda R, Sapp J, Page CP. Incidence and hospital stay for cardiac and pulmonary complications after abdominal surgery. J Gen Intern Med 1995;10:671-678.
2. Smetana GW. Preoperative pulmonary evaluation. N Engl J Med 1999;340:937-944.
3. Fisher BW, Majumdar SR, McAlister FA. Predicting pulmonary complications after nonthoracic surgery: a systematic review of blinded studies. Am J Med 2002;112:219-225.
4. Fogh J, Wille-Jorgensen P, Brynjolf I, Thorup J, Jorgensen T, Bording L, Kjaergaard J. The predictive value of preoperative perfusion/ventilation scintography, spirometry and x-ray of the lungs on postoperative pulmonary complications. A prospective study. Acta Anesthesiol Scand 1987;31:717-721.
5. Williams-Russo P, Charlson ME, Mackenzie CR, Gold JP, Shires GT. Predicting postoperative pulmonary complications. Is it a real problem? Arch Intern Med 1992;152:1209-1213.
6. Rao MK, Reilley TE, Schuller DE, Young DC. Analysis of risk factors for postoperative pulmonary complications in head and neck surgery. Laryngoscope 1992;102:45-47.
7. Ephgrave KS, Kleiman-Wexler R, Pfaller M, Booth B, Werkmeister L, Young S. Postoperative pneumonia: a prospective study of risk factors and morbidity. Surgery 1993;114:815-821.

8. Lawrence VA, Dhanda R, Hilsenbeck SG, Page CP. Risk of pulmonary complications after elective surgery. Chest 1996;110:744-750.
9. Hall JC, Tarala RA, Hall JL. Respiratory insufficiency after abdominal surgery. Respirology 1996;1:133-138.
10. Mitchell CK, Smoger SH, Pfeifer MP, Vogel RL, Pandit MK, Donnelly PJ, Garrison RN, Rothschild MA. Multivariate analysis of factors associated with postoperative pulmonary complications following general elective surgery. Arch Surg 1998;133:194-198.
11. McAlister FA, Khan NA, Straus SE, Papaioakim M, Fisher BW, Majumdar SR, Gajic O, Daniel M, Tomlinson G. Accuracy of the preoperative assessment in predicting pulmonary risk after non-thoracic surgery. Am J Resp Crit Care Med 2003;167:741-744.
12. Lijmer JG, Mol BW, Heisterkamp S, Bonsel GJ, Prins MH, van der Meulen JHP, Bossuyt PMM. Empirical evidence of design-related bias in studies of diagnostic tests. JAMA 1999;282:1061-1066.
13. Arozullah AM, Daley J, Henderson WG, Khuri SF, for the National Veterans Administration Surgical Quality Improvement Program. Multifactorial risk index for predicting postoperative respiratory failure in men after major noncardiac surgery. Ann Surg 2000;232:242-253.
14. Arozullah AM, Khuri SF, Henderson WG, Daley J, for the Participants in the National Veterans Affairs Surgical Quality Improvement Program. Development and validation of a multifactorial risk index for predicting

postoperative pneumonia after major noncardiac surgery. Ann Intern Med 2001;135:847-857.

15. Lawrence VA, Page CP, Harris GD. Pre-operative spirometry before abdominal operations: a critical appraisal of its predictive value. Arch Intern Med 1989;149:280-285.
16. Cheatham ML, Chapman WC, Key SP, Sawyers JL. A meta-analysis of selective versus routine nasogastric decompression after elective laparotomy. Ann Surg 1995;221:469-476.
17. Keenan SP, Heyland DK, Jacka MJ, Cook D, Dodek P. Ventilator-associated pneumonia: prevention, diagnosis, and therapy. Crit Care Clin 2002;18:107-125.

TABLE 1: The association between continuous preoperative/operative variables and the occurrence of postoperative pulmonary complications.

Variable	Proportion of previous studies reporting significant association*	In this study		
		Postoperative pulmonary complication (n=28)	No postoperative pulmonary complication (n=1027)	P value
Age	1/8	68.6 (64.3 – 72.9)	54.7 (53.7 - 55.6)	<0.001
Body Mass Index	1/3	26.9 (25.5 - 28.3)	27.9 (27.5 – 28.2)	0.24
In smokers, mean pack years smoked	2/2	29.7 (22.6 – 36.9)	19.6 (18.1 – 21.0)	0.01
Forced expiratory volume in one second (FEV1)	2/6	1.98 (1.72 – 2.25)	2.70 (2.65 – 2.75)	<0.001
Forced vital capacity (FVC)	1/5	3.04 (2.70 – 3.38)	3.49 (3.43 – 3.55)	0.02
FEV1/FVC Ratio	1/1	65.5 (61.2 – 69.7)	77.4 (76.8 – 77.9)	<0.001
Oxygen saturation on room air	2/4	96.1 (95.0 – 97.3)	97.3 (97.1 – 97.4)	0.07
Duration of anesthesia	3/5	3.76 (2.69 – 4.83)	2.05 (1.94 – 2.16)	0.004

Continuous variables all expressed as mean (with 95% confidence intervals).

* Derived from references 3-11

TABLE 2: The association between binary preoperative/operative variables and the occurrence of postoperative pulmonary complications.

Variable	Proportion of previous studies reporting significant association*	In this study		
		Number of patients with particular finding	Odds Ratio (95% Confidence Interval)	P value
Age $\geq$ 65 years	See table 1	332	5.73 (2.49-13.15)	<0.001
Male gender	0/8	531	1.54 (0.72-3.32)	0.27
Ever smoked (vs. never)	1/7	630	2.06 (0.87-4.89)	0.12
Current smoker (within 2 weeks of operation)	0/1	218	0.83 (0.31-2.21)	0.82
Smoked $\geq$ 40 pack years	See table 1	94	2.91 (1.15-7.37)	0.03
Recent (within 2 weeks) upper respiratory tract infection	0/2	90	1.82 (0.62-5.38)	0.29
History of chronic obstructive pulmonary disease	2/7	54	3.26 (1.09-9.74)	0.05
History of asthma	0/3	104	2.03 (0.76-5.48)	0.19
Daily productive cough	1/2	100	2.71 (1.07-6.84)	0.04
Exercise capacity $\leq$ 2 blocks or 1 flight of stairs	3/3	126	0.88 (0.26-2.96)	1.00
Body Mass Index $\geq$ 30	See table 1	339	0.57 (0.23-1.42)	0.22
Positive cough test	1/1	74	3.84 (1.51-9.80)	0.01
Positive wheeze test	1/1	40	0.94 (0.12-7.08)	1.00
Forced Expiratory Time $\geq$ 9 s	1/1	31	4.28 (1.22-15.02)	0.04
Maximum laryngeal height $\leq$ 4 cm	1/1	166	1.17 (0.44-3.12)	0.79

Wheezing on standard auscultation	1/4	34	2.39 (0.54-10.51)	0.23
Upper abdominal incision	1/4	92	4.49 (1.92-10.50)	0.002
General anesthesia	0/4	931	1.11 (0.33-3.74)	1.00
Duration of operation ≥ 2.5 hours	See table 1	321	5.07 (2.27-11.33)	<0.001
Perioperative nasogastric tube	2/2	66	13.50 (6.08-29.96)	<0.001
FEV1 < 1 L	See table 1	14	6.51 (1.38-30.56)	0.05
Chest radiograph abnormal	1/4	44	1.80 (0.41-7.85)	0.33

In the case of operative variables, referent groups were: all other surgeries vs. upper abdominal incision, regional or spinal anesthesia vs. general anesthesia, and < 2.5 hour duration vs. ≥ 2.5 hours.

* Derived from references 3-11

ONLINE DATA SUPPLEMENT

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Finlay A. McAlister,[1] MD MSc

Kimberly Bertsch,[1] BScN MSc

Jeremy Man,[1] BMSc

John Bradley,[1] MD

Michael Jacka,[2] MD MSc

METHODS:

Design:

This prospective cohort study was conducted in the Pre-Admission Clinic at the University of Alberta Hospital. We approached consecutive adult patients (with or without pre-existing lung disease) who were scheduled to undergo elective non-thoracic surgery with planned postoperative admission- 98% of those approached agreed to participate in this study. We excluded patients who were already hospitalized or mechanically ventilated at the time of preoperative assessment, or those patients with a history of sleep apnea requiring CPAP, neuromuscular disease, or medical problems that precluded their participation (such as cognitive impairment).

One investigator performed a standardized history, physical examination, and spirometry on study participants preoperatively with methods and interpretation of physical examination maneuvers established a priori. Postoperatively, a second investigator (a physician blinded to the results of the preoperative evaluation and not involved in the patient's ongoing care) collected outcomes through review of chart, laboratory, and radiologic data for each patient. Perioperative laboratory tests (such as chest radiographs or arterial blood gases) and management were left to the discretion of the attending physicians caring for these patients. Data on length of stay was also collected.

Variables Collected and Definition of Outcomes:

Using standardized data collection sheets and definitions/methods of performing the exam maneuvers, we collected the items listed in Tables 1 and 2 in the print version of the manuscript. We defined COPD as a prior diagnosis assigned by a physician, irrespective of whether chronic treatment was required. The physical examination maneuvers included:

-the cough test (performed by having the patient take a deep inspiration and cough once, positive test defined as recurrent coughing after first cough),

-the wheeze test (performed by having the patient take 5 deep inspirations/expirations and then auscultating between the shoulder blades posteriorly to determine the presence or absence of wheezing),

-forced expiratory time (performed by having the patient take a deep inspiration and then exhale completely through an open mouth, with an abnormal value defined as $\geq$ 9 seconds- this has previously been shown to be an accurate sign of obstructive airways disease compared to pulmonary function tests[E1]),

-maximum laryngeal height (the distance between the top of the thyroid cartilage and the suprasternal notch at the end of expiration, with an abnormal value defined as $\leq$ 4 cm- this has also previously been shown to be an accurate sign of obstructive airways disease compared to pulmonary function tests[E2]), and

-the presence or absence of wheezing on standard chest auscultation.

We only included patients undergoing non-thoracic surgery, and classified surgical types as “upper abdominal incision” vs. “other surgeries” a priori. Other surgeries included lower abdominal incisions (for example, inguinal hernia repairs or gynecologic surgery where the incision did not extend above the umbilicus), laparoscopic intra-abdominal operations, orthopedic surgery (lower/upper limbs or spine, including laparoscopic joint operations), urologic surgery (for example, transurethral resections of the prostate), neurosurgical operations, and assorted minor plastic surgery, opthalmologic, or Ear-Nose-Throat procedures.

The primary outcome was the occurrence of a symptomatic and clinically significant postoperative pulmonary complication prior to hospital discharge or by the seventh postoperative day (whichever came first). Postoperative pulmonary complications were defined as: respiratory failure requiring invasive or non-invasive mechanical ventilation (as per the decision of the attending physician caring for the patient, independent of the study investigators), pneumonia (defined using the Centers for Disease Control definition for postoperative pneumonia, as per a recent cohort study on postoperative pneumonia- see table E1),[E3,E4] or atelectasis of lung or lobe requiring bronchoscopic intervention (the decision for bronchoscopy was made by the attending physician looking after the patient, independent of the study investigators, and was based on non-standardized functional indications such as hypoxia or respiratory distress). Only the first of these complications occurring in any one patient was used for this analysis and outcomes were included if any patients were re-admitted to hospital with a pulmonary complication within 7 days of surgery.

Data Analysis:

To evaluate the relationship between the perioperative variables and postoperative pulmonary complications, we used the Chi-square test or Fisher's exact test for dichotomous variables and the t-test for continuous variables. After confirming normality, the continuous variables (age, pack years of smoking, body mass index, FEV1, FVC, and duration of anesthesia) were dichotomized using cut-points previously described in the literature.[E5,E6] We also performed receiver operating curve analyses to determine whether new cut-points for these variables would be more appropriate. Multivariate logistic regression analyses were performed incorporating all factors with $p<0.20$ on bivariate analyses and a prevalence of at least 1%, as well as other variables felt to be potentially clinically important, using the backward stepwise selection technique and accepting statistical significance at $p<0.05$. Continuous variables in the model were tested for linearity and replaced with a dichotomized variable if not linear. Further, as including more than one spirometry variable would create problems with collinearity, we selected FEV_1 for the model.

Ethics:

This study was approved by the University of Alberta Health Research Ethics Board and the study sponsors had no input into the design, conduct, analysis, or reporting of this study.

REFERENCES:

E1. Straus SE, McAlister FA, Deeks JJ, Sackett DL for the CARE-COAD2 Investigators. The accuracy of history, wheezing, and forced expiratory time in diagnosing chronic obstructive airways disease. J Gen Intern Med 2002;17:684-88.

E2. Straus SE, McAlister FA, Sackett DL, Deeks JJ, for the CARE-COAD1 Group. The accuracy of patient history, wheezing, and laryngeal measurements in diagnosing obstructive airways disease. JAMA 2000;283:1853-7.

E3. Arozullah AM, Khuri SF, Henderson WG, Daley J, for the Participants in the National Veterans Affairs Surgical Quality Improvement Program. Development and validation of a multifactorial risk index for predicting postoperative pneumonia after major noncardiac surgery. Ann Intern Med 2001;135:847-57.

E4. Garnder JS, Jarvis WR, Emori T, et al. CDC definitions for nosocomial infections, 1988. Am J Infect Control 1988;16:128-40.

E5. Fisher BW, Majumdar SR, McAlister FA. Predicting pulmonary complications after nonthoracic surgery: a systematic review of blinded studies. Am J Med 2002;112:219-25.

E6. McAlister FA, Khan NA, Straus S, et al. Accuracy of the preoperative assessment in predicting pulmonary risk after non-thoracic surgery (the CARE-PREOP1 Study). Am J Resp Crit Care Med 2003;167:741-4.

Table E1: Definition of Postoperative Pneumonia (adapted from references E3 and E4)

Postoperative pneumonia defined as: **-new or progressive infiltrate on chest radiography OR crackles or dullness on percussion of the chest** **-AND, any of: new onset purulent sputum, change in character of chronic sputum, positive blood cultures, or isolation of pathogen from sputum, transtracheal aspirate, bronchial brush, or biopsy**