Original Article

Preoperative pulmonary function testing does not predict postoperative pulmonary complications after elective abdominal surgery：a case-control study using conditional logistic regression analysis

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Abstract

Background and Aims：There is controversy regarding the ability of preoperative pulmonary function testing to predict postoperative pulmonary complications after elective abdominal surgery. This study was undertaken to determine whether preoperative pulmonary function tests are helpful in stratifying the risk of developing postoperative pulmonary complications in patients undergoing elective laparotomy.
Materials and Methods：We conducted a retrospective case-control study, and identified 19 patients with postoperative pulmonary complications and compared these patients with 64 control patients matched for type of operation, age, and gender to compare pre- and intraoperative variables.
Results：Conditional logistic regression analyses showed that none of the results from spirometry testing were significantly associated with the development of postoperative pulmonary complications. Serum albumin level（<3.9g/dl）was the only variable independently associated with the development of postoperative pulmonary complications among all of pre- and intraoperative variables investigated.
Conclusions：Preoperative pulmonary function testing did not predict the risk of developing postoperative pulmonary complications in patients undergoing elective abdominal surgery. Based on the results of this study, the routine use of preoperative spirometry should be reconsidered.
（Keywords：Elective Surgical Procedures, Laparotomy, Postoperative Complications, Preoperative care, Spirometry.）

Introduction

Abdominal surgery can be associated with significant pulmonary and cardiac complications[1]. Postoperative pulmonary complications（PPC）are part of the risk of surgery because they are as common as cardiac complications and contribute similarly to morbidity, mortality and length of hospital stay[2-5]. Estimating the risk of developing PPC may be as crucial as cardiac evaluation to stratify a patient's overall risk.

Although pulmonary function testing before lung resection and coronary artery bypass is well accepted, its routine use before non-thoracic surgery has been controversial[5, 6]. In 2006, the American College of Physicians developed the first clinical guidelines for preoperative pulmonary evaluation in patients undergoing non-cardiothoracic operations, recommending against routine preoperative pulmonary function testing because its value in stratifying risk remained unproven[6-8]. However, two prospective cohort studies by McAlister et al.[9, 10] found an association between preoperative pulmonary function testing and PPC. These studies found that the forced expiratory volume in one second, less than one liter, is an adverse prognostic factor[9, 10].

Uncertainty still remains regarding the ability of

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preoperative pulmonary function testing to predict the risk of PPC after non-thoracic surgery. We undertook this study using conditional logistic regression analysis to evaluate the ability of preoperative pulmonary function testing to predict the risk of developing PPC in patients undergoing elective laparotomy.

Methods

Selection of the study subjects

We conducted a retrospective case-control study at Jichi Medical University Hospital, an 1130-bed teaching hospital in Tochigi, Japan. Study subjects were selected from the total group of 3,889 patients who underwent abdominal surgery during the three-year period between January 2007 and December 2009. This study was approved by the Ethics Committee at Jichi Medical University Hospital. Patients with PPC were identified in a computerized registry, which includes all patients with postoperative complications occurring before discharge.

This study design was intentionally selected because of the rarity of PPC, which greatly complicates the conduct of a randomized prospective trial. Rather, by reviewing patients who did suffer PPC, and then looking back at the value of preoperative pulmonary function testing, this study design enables analysis in the rare cases of PPC.

PPC were defined based on explicit criteria described by McAlister et al.[10] including：(1) respiratory failure requiring mechanical ventilation, (2) pneumonia (defined using the Centers for Disease Control and Prevention definition for postoperative pneumonia), (3) atelectasis requiring bronchoscopy, or (4) pneumothorax or pleural effusion requiring percutaneous intervention. The decision to use interventions such as mechanical ventilation, bronchoscopy, or others was left to the discretion of the attending physician[10]. We collected data on the occurrence of PPC within the first seven postoperative days through review of the medical chart, laboratory, and radiology data. Only the first PPC occurring in any one patient was analyzed.

The study subject selection process is shown in Figure 1. There were 80 patients in the registry with pulmonary complications (2.0% of all patients who underwent surgery during the study period). We excluded patients who underwent emergency operations (n=29) and thoracic surgery such as esophagectomy (n=10). We also excluded patients who did not meet the above-mentioned criteria for PPC (n=22), leaving 19 patients who met all study criteria. We then selected up to four control patients without PPC during the identical period for each of the 19 study subjects with PPC by matching the type of surgical procedure, age(± 5 years), and gender in order to avoid bias due to specific surgical procedures, age, or gender in assessing the risk factor for PPCs. When five or more potential control patients met the criteria, the four patients whose operation date was nearest to the matched case were selected as the control subjects. We were able to find four control patients for 14 of the study subjects. We found only three matched controls for one patient who underwent a gastrectomy, two controls for one study subject who underwent a sigmoid colon resection, and one control for three study subjects who underwent choledochojejunostomy, hepatic resection, and a high anterior resection, respectively. Overall, 64 matched patients satisfied all criteria as controls.

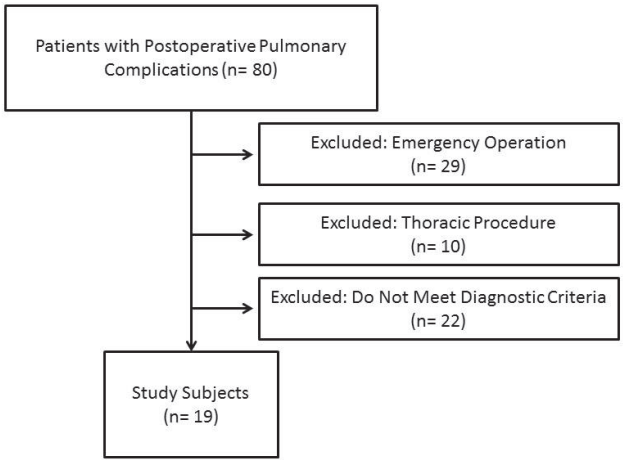

Figure 1. Study subject selection process.
Of 80 patients with postoperative pulmonary complications after surgery, 19 patients were selected as study subjects after excluding 61 patients who did not meet all of the study criteria.

Data was then extracted from the medical records to identify preoperative and intraoperative variables potentially associated with PPC. We defined all comorbidities previously diagnosed by a physician[10] and cardiac complications previously diagnosed as either arrhythmia or ischemic heart disease. The lung examination was defined as normal (no abnormalities noted) or abnormal (rales, crackles, or wheezes) based on the preoperative medical record[1]. Functional dependency was the need for equipment such as a cane in daily living[6]. We also determined metabolic equivalents, which represent the degree of a patient`s daily physical activity and have been used to assess cardiovascular risk for non-cardiac surgery[11]. A patient's physical functional capacity is evaluated by using a standardized questionnaire and then classified into three categories (e.g., 4 metabolic equivalents：low, more than 4 to 7 metabolic equivalents：moderate, and more than 7 metabolic equivalents：good). A smoker is defined as having a history of smoking at any point in the past. Preoperative serum albumin level and pulmonary function testing data were available for all patients. Other preoperative variables also included body mass index and the American Society of Anesthesiologists classification[1, 6]. We used the American Society of Anesthesiologists classification as recorded in the anesthesiology record. Intraoperative variables included

operative time, crystalloid replacement volume, urine output volume, blood transfusion volume, and estimated blood loss[12].

Statistical Analysis

All data analysis was performed under the supervision of an epidemiologist (YN). Data were described non-parametrically, analyzed using two-sided analysis, and considered significant for $p< 0.05$. A simple comparison analysis of unmatched descriptive data was performed using the chi square and Fisher`s exact tests for categorical data, and the Mann-Whitney U tests for continuous data. Variables with $p< 0.1$ were then selected as potential risk factors for pulmonary complications, and conditional logistic regression analyses performed for these variables because cases and control were matched by surgical procedure, age, and gender. Variables were dichotomized based on either cut-off points in the literature or standard references[6, 7, 9, 10, 12]. Statistical analyses were performed using Intercooled STATA 8.2 for Windows (STATA Corp., TX, USA).

Results

Pulmonary complications among the 19 patients with PPC in this study included pneumonia (N=9, 48%), respiratory failure (N=5, 26%), pleural effusion (N=4, 21%) and atelectasis (N=1, 5%) (Table 1). The mean age among study subjects and controls was 72 years in both groups. Most of the patients in both groups were male (Subjects 95%, Controls 94%). Upper abdominal surgery predominated (74%, 77%) including gastric procedures (58%, 67%), biliary procedures (5%, 2%), and hepatic procedures (5%, 2%). Lower abdominal surgery (colorectal surgery) represented 26% and 23% of the procedures in subjects and controls respectively (Table 2). There were no significant differences in the distribution of procedures in the two groups.

Tables 3 and 4 show unmatched descriptive analyses of preoperative variables and spirometry data, respectively. Study subjects did not differ significantly from control patients in regard to the following variables: comorbidities, abnormal results of the physical examination, functional dependency, metabolic equivalents, smoking status, pack-years of smoking, body mass index, serum albumin level, and American Society of Anesthesiologists classification (Table 3).

Table 1. Composition of Pulmonary Complications

Pulmonary complications	n (%)
Pneumonia	9 (47.4)
Respiratory failure	5 (26.3)
Effusion	4 (21.1)
Atelectasis	1 (5.3)
Total	19 (100)

Table 2. Characteristics of Patients With and Without Pulmonary Complications

	Cases (n=19)	Control (n=64)
Age, years, median (IQR)	72 (9.5)	72 (11)
Men, n (%)	18 (94.7)	60 (93.8)
Types of laparotomy, n (%)		
Upper Abdominal Surgery	14 (73.7)	49 (76.6)
Gastric procedures	11 (57.8)	43 (67.2)
Biliary procedures	1 (5.2)	1 (1.6)
Hepatic procedures*	1 (5.2)	1 (1.6)
Pancreatic procedures	1 (5.2)	4 (6.3)
Lower Abdominal Surgery	5 (26.3)	15 (23.4)
Colorectal procedures	5 (26.3)	15 (23.4)

IQR: interquartile range.

*Hepatectomy associated with right hemicolectomy.

Among the preoperative variables reviewed, three were considered possible risk factors with $p<0.1$: pack-years of smoking ($p=0.054$), serum albumin level ($p=0.067$), and the American Society of Anesthesiologists classification ($p=0.07$). In addition, several values measured by pulmonary function testing showed significant association with developing PPCs including: forced vital capacity ($p=0.047$), percent predicted forced vital capacity ($p=0.02$), forced expiratory volume in one second ($p=0.03$), and percent predicted forced expiratory volume in one second ($p=0.049$) (Table 4).

Study subjects and controls were well matched for variables related to the conduct of the operation including operative time, crystalloid replacement volume, urine output volume, blood transfusion volume and estimated blood loss. Comparison of intraoperative variables between patients with PPC and control patients did not show any significant differences ($p>.05$) (Table 5).

By using possible risk variables from unmatched descriptive analyses, we then performed conditional logistic regression analyses. As shown in Table 6, analysis revealed that none of spirometry data were significantly associated with PPC. Serum albumin level (<3.9g/dl) was the only variable independently associated with the development of PPC ($p=0.037$).

Discussion

Postoperative pulmonary complications occur as frequently as postoperative cardiac complications and similarly influence postoperative morbidity and mortality[2-5]. Optimum preoperative pulmonary evaluation is an important consideration to accurately stratify risk. The role of pulmonary function testing in preoperative pulmonary evaluation in elective abdominal surgery has been

Table 3. Preoperative Variables

		Cases (n=19)	Control (n=64)	p - value
Coexisting disorders, n, (%)				
COPD		2 (10.5)	7 (10.9)	1
Asthma		0 (0)	3 (4.7)	1
Bronchodilator use		2 (10.5)	9 (14.1)	1
Congestive heart failure		1 (5.3)	0 (0)	0.23
Hypertention		11 (57.8)	42 (65.6)	0.59
Cardiac complication		4 (21.1)	10 (15.6)	0.73
Diabete melitus		4 (21.1)	14 (21.9)	1
Abnormal results of lung examination, n, (%)		1 (5.3)	4 (6.3)	1
Functional dependency, n, (%)		1 (5.3)	1 (1.6)	0.41
METs (degree of activity), n, (%)	<4 (low)	2 (10.5)	11 (17.2)	
	4 to 7 (moderate)	4 (21.1)	12 (18.8)	0.76
	>7 (good)	12 (63.1)	36 (56.3)	
	Not recorded	1 (5.3)	5 (7.8)	
Smoker, n, (%)		14 (73.7)	54 (84.4)	0.32
Pack-years smoking, median (IQR)		20 (38.8)	40 (36.3)	0.054
Body mass index, kg/m^2 median (IQR)		22.4 (4.6)	22.9 (5.6)	0.61
Serum albumin level, g/dl, median (IQR)		3.7 (0.7)	3.9 (0.7)	0.067
ASA classification, n, (%)	1	0 (0)	3(4.7)	
	2	12 (63.2)	52 (81.3)	
	3	7 (36.8)	9(14.1)	0.07
	4	0 (0)	0 (0)	
	5	0 (0)	0 (0)	

IQR: interquartile range; COPD: chronic obstructive pulmonary disease; METs: metabolic equivalents; ASA: American Society of Anesthesiologists.

Table 4. Preoperative Spirometric Data

	Cases (n=19)	Control (n=64)	p - value*
FVC, L, median (IQR)	3.0 (0.8)	3.5 (1.1)	**0.047**
Percent predicted FVC, median (IQR)	99.4 (21.6)	109.1 (27.1)	**0.02**
FEV_1, L, median (IQR)	1.8 (0.6)	2.5 (0.9)	**0.03**
Percent predicted FEV1, median (IQR)	99.2 (23.9)	109.3 (34.1)	**0.049**
FEV_1/FVC, median (IQR)	68.3 (16.8)	67.8 (12.0)	0.73
Percent predicted FEV_1/FVC, median (IQR)	103.6 (29.1)	104.0 (18.8)	0.91

IQR: interquartile range;

FVC: forced vital capacity;

FEV_1: forced expiratory volume in 1 second.

*Significant p-values are expresed in bold.

Table 5. Intraoperative variables

	Cases (n=19)	Control (n=64)	p - value
Operation time, min, median (IQR)	216.0 (97.0)	231.5 (101.0)	0.39
Crystalloid replacement volume, mL, median (IQR)	2700 (1125)	3175 (1100)	0.06
Urin output volume, mL, median (IQR)	300 (358)	310 (300)	0.87
Blood transfusion volume, mL, median (IQR)	0 (0)	0 (0)	0.73
Bleeding volume, mL, median (IQR)	210 (295)	390 (483)	0.25

IQR: interquartile range.

Table 6. Factors associated with PPC

Factor	No. of posive cases, n (%)		conditional logistic regression	
	case	control	Odds ratio (95%CI)	p-value*
Pack-year smoking (≥40)	8 (42.1)	35 (54.7)	0.58 (0.20-1.68)	0.314
Serum-albumin (<3.9g/dl)	14 (73.7)	29 (45.3)	4.04 (1.09-14.97)	**0.037**
ASA (≥3)	7 (36.8)	9 (14.1)	2.92 (0.93-9.12)	0.066
FVC (<1.5L)	0 (0)	2 (3.1)	n/a	n/a
%FVC (<80%)	2 (10.5)	3 (4.7)	1.31 (0.18-9.53)	0.78
FEV1 (<1L)	0 (0)	1 (1.6)	n/a	n/a
%FEV1 (<80%)	2 (10.5)	7 (10.9)	0.85 (0.17-4.22)	0.85
Crystalloid replacement volume (>6L)	0 (0)	0 (0)	n/a	n/a

n/a: not applicable .

ASA: American Society of Anesthesiologists' classification

FVC: Forced Vital Capacity

% FVC: percent predicted FVC

FEV1: Forced Expiratory Volume in one second

%FEV1: percent predicted FEV1

*Significant p-value is expressed in bold.

Table 7. Comparison with eight previous studies in the literature

Author	Year	Reference	Study Design	Patient Group	No. of Patients	No. (%) of Cases
Kispert	1992	17	Retrospective	Vascular surgery	147	19 (12.9)
Kroenke	1992	18	Retrospective	Severe COPD (FEV_1<50%)	107	31 (29.0)
Kroenke	1993	16	Retrospective	Severe COPD (FEV_1<50%)	26	6 (23.0)
Jayr	1993	19	Prospective	Major abdominal vascular surgery	51	12 (23.5)
Wong	1995	20	Retrospective	Severe COPD (FEV_1<50%)	105	39 (37.0)
Kocabas	1996	21	Prospective	Upper abdominal surgery	60	21(35.0)
Barisione	1997	22	Prospective	Upper abdominal surgery	361	49 (14.0)
Mitchel	1998	23	Prospective	Nonthoracic surgery	148	16 (11.0)
Present Study	-	-	Retrospective	Abdominal Surgery	3889	19 (0.5)

controversial[2]. Before the 1990s, studies suggested that patients were at risk of developing pulmonary complications after abdominal surgery if their forced vital capacity and forced expiratory volume in one second values were less than 70 percent of predicted values and the ratio of these two parameters is less than 65 percent[13].

However, a critical review in 1989 of pulmonary function testing as a preoperative screening test found methodological errors in all 22 previous studies that investigated its predictive value[14], and concluded that the predictive value of pulmonary function testing before elective abdominal surgery is unproven. Subsequent

studies in the 1990s similarly found that pulmonary function testing is not useful in predicting postoperative pulmonary complications after elective abdominal surgery[1, 15, 16]. In 2006, the American College of Physicians published clinical guidelines for preoperative pulmonary evaluation for patients undergoing non-cardiothoracic surgery and recommended against routine preoperative pulmonary function testing because its ability to predict the risk of PPC remained unproven[6-8]. However, two subsequent prospective cohort studies by McAlister et al.[9, 10] indicated that there is an association between preoperative pulmonary function testing results and the development of PPC. These inconsistent results may cause confusion among clinicians in deciding whether or not to perform pulmonary function testing prior to elective abdominal surgery.

There are two possible reasons for the inconsistent results regarding the predictive value of pulmonary function testing. First, there is variation in the definition of PPCs[1, 14-16]. A lack of uniform outcome measures may be responsible for differences in the reported incidence of pulmonary complications[2] and lead to mixed conclusions. The second possible reason is that not all patients underwent preoperative pulmonary function testing in previous studies[1, 8, 9, 12, 15]. In general, the criteria for deciding which patients should undergo pulmonary function testing are not explicit, leaving the decision to perform the test at the discretion of the physician[1, 8, 9]. As a result, the odds ratio of pulmonary function testing values could be overestimated or underestimated due to selection bias depending on how patients were selected to undergo pulmonary function testing. In fact, the study by McAlister et al. showed that patients who did not undergo pulmonary function testing had more PPCs than patients who underwent pulmonary function testing[9], highlighting the difficulty in determining which patients should undergo preoperative pulmonary function testing. The present study avoided these problems by using the following strategies：(1) explicitly defining PPC and measuring only clinically significant outcomes that required interventions and (2) collecting data from a study group in which every patient underwent pulmonary function testing, which is the standard of care in our institution.

The result of this study showed that serum albumin level <3.9g/dl was the only significantly associated preoperative variable and pulmonary function testing was not helpful in stratifying risk of developing PPC for patients undergoing elective abdominal surgery. Although forced vital capacity, percent predicted forced vital capacity, forced expiratory volume in one second and percent predicted forced expiratory volume in one second were significantly associated with PPC in initial analyses of descriptive unmatched data (Table 4), significant differences were not present when analyzed using a conditional logistic regression model (Table 6). The results of this study are consistent with the majority of similar studies that assessed the predictive value of pulmonary function testing before elective abdominal surgery.

Of eight studies conducted since 1990 in which all patients underwent preoperative spirometry, four studies found no predictive value of pulmonary function testing, three found a limited predictive value inferior to data from the physical examination or American Society of Anesthesiologists' classification[16-23] (Table 7). Although previous studies showed that a forced expiratory volume in one second less than one liter or a forced vital capacity less than 1.5L were significantly associated with the development of PPC, the study population in this study had very few patients who met these criteria[9, 10, 20]. For example, the percentages of patients with forced expiratory volume in one second less than one liter were 0% and 1.6% among study subjects and controls, respectively. A low prevalence of severely low lung capacity in this study population could partially explain why this study did not show a significant association between spirometry data and PPC. However, this may not be the case because two previous studies demonstrated that the severity of chronic obstructive pulmonary disease measured by spirometry was not an independent predictor of PPC even among patients with severe chronic obstructive pulmonary disease (defined as percent predicted forced expiratory volume in one second less than 50) with mean forced expiratory volume in one second ranging between 1.06 – 1.10[16, 18].

Although this study has several strengths, including the use of explicit definitions for PPC, evaluation of laboratory predictors for all patients, rigorous case selection process, and an increased statistical power by matching multiple control patients per cases, there are some limitations. The study was retrospective, which results in some missing data. The data for metabolic equivalents in six patients were not available.

One strength of this study is that data for 3889 patients were reviewed, all of who underwent preoperative pulmonary function testing. This provides a true value for the incidence of pulmonary complications of 0.5%. There have been a number of studies in the literature, but no studies to date have a patient population similar in size to the present study[10, 16-23] (Table 7), and many previous studies evaluated only a fraction of the total patients who underwent surgery with pulmonary function testing[1, 9, 10, 12, 15].

In order to compensate for the relatively small number of patients who had PPC we performed a case-control study, which is a valid statistical approach when the incidence of a condition is low, with the consultation of a full-time, expert statistician (YN). One limitation of this methodology is that we were unable to find four well-matched controls for five patients as mentioned in the Methods section, partly due to the rigorous matching of age, gender and surgical procedure.

The small sample size of patients who developed PPC is partly due to the explicit definition of PPC in the study that only included clinically significant outcomes. It is also due to the relative infrequency of PPC. The study by McAlister had a study population of 1,055 patients and had 28（2.8%）patients who developed PPC with the same definition used in the present study[10]. The number of patients in the present study with PPC is comparable to eight previous studies in the literature（median 20, interquartile range 18）[16-23]（Table 7）.

Optimal study size is generally determined by a power analysis. However, due to the fact that multiple risk factors were analyzed, a power analysis to determine the optimal sample size is not possible. However, the statistical analysis using a ratio of controls to study subjects of four to one is statistically appropriate to draw valid conclusions. The careful case-controlled design of this study compensates for the relatively small sample size. Considering the remaining uncertainty regarding the ability of preoperative pulmonary function testing to predict the risk of pulmonary complications after non-thoracic operations, a prospective study with a larger study population may be warranted in the future.

In conclusion, this study shows that preoperative pulmonary function testing is not useful in assessing the risk of developing postoperative pulmonary complications after elective abdominal surgery, consistent with the 2006 guidelines by the American College of Physicians. These results further reinforce the argument against the routine use of spirometry before elective abdominal surgery, based on data from a large patient cohort, all of whom underwent preoperative pulmonary function testing. Even though spirometry is a relatively inexpensive test that is not invasive, its routine use before non-thoracic surgery should be reconsidered since its benefit remains unproven.

Declaration of interest：The authors have no conflict of interest to declare.

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腹部予定手術後肺合併症の予測における術前肺機能検査の有用性の検討

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要　約

背景と目的：開腹術後の肺合併症リスク予測における術前肺機能検査の有用性に関しては議論がある。肺機能検査が，腹部手術を予定している患者の肺合併症発症予測に有用か，臨床的検討を行った。
方法：後ろ向きケースコントロール研究を行い，術後肺合併症を来した19例と，年齢，性別，術式でマッチさせた術後肺合併症を来さなかったコントロール64例の術前，術中因子を比較した。
結果：条件付きロジスティック回帰分析では，術前肺機能検査のいずれの値も，術後肺合併症と有意な関連が見られなかった。検討した術前，術後因子の中で，血清アルブミン値（<3.9g/dl）が唯一術後肺合併症の独立関連因子であった。
考察：本研究では術前肺機能検査は，予定腹部手術後の肺合併症リスク予想には有用ではないとの結果が得られた。本研究の結果に基づき，現在腹部手術前にルーチンで行っている術前肺機能検査の有効性について，再度検討すべきと思われる。
（キーワード：予定手術，開腹手術，術後合併症，術前ケア，肺機能検査）

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