Pre-operative and 24 hour Post-operation Changes of Peak Expiratory Flow Rate Prediction Post-operation Pulmonary Complications

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ABSTRACT

Background: Post-operative pulmonary complications (PPCs) are common problems after abdominal operations. The incidence varies from 10 to 69% for atelectasis and 9 to 40% for post-operation pneumonia. Many studies have investigated risk factors and risk indices for predicting PPCs. However, no definite predictors for PPCs have yet been described.

Objective: To develop a simple, reliable, and safe diagnostic tool for early detection of post-operation pulmonary complications.

Methods: A series of 151 consecutive patients scheduled for elective abdominal operations were studied between 1 September 2003 and 31 August 2004 at The Department of Surgery, Faculty of Medicine at Siriraj Hospital. The patients were measured for peak expiratory flow rate (PEFR) a night before operation, followed by every 24 hr post-operation. The data was analyzed using univariate and multivariate regression analyses with respect to post-operation pulmonary complications.

Results: A total of 15 patients (9.9%) developed post-operation pulmonary complications. Univariate analysis demonstrated that preoperative PEFR (PrePEFR) and 24 hr post-operation PEFR (PostPEFR) could predict PPCs. Using multivariate regression analyses, the PEFR Score was developed and calculated as (17.24 x Malignant)-(0.16 x PostPEFR). A cut point value was -4.68. The diagnostic sensitivity was 80% and specificity was 73.5%.

Conclusion: 24 hours post-operation PEFR is a simple and valuable bedside method for predicting PPCs.

Keywords: Peak expiratory flow rate, post-operative pulmonary complications

INTRODUCTION

Post-operation pulmonary complications (PPCs) is one of the most common clinical problems after abdominal operations. Their incidence varies from 10 to 69% for atelectasis[1,2] and for post-operation pneumonia from 9 to 40%.[3] There are many predictors to predict the development of the PPCs such as age, history of cancer, underlying pulmonary dysfunction, smoking, site of surgical incision, anesthetic time and nasogastric tube placement.[4,5] The role of pulmonary function testing in risk assessment prior to abdominal surgery is not clear. There are significant reductions post-operationally (24 hr) in forced expiratory volume in 1 second (FEV1), peak expiratory flow rate (PEFR), forced vital capacity (FVC), and expiratory reserve volume (ERV).[6,7] A systematic review study showed only

FEV1 and PEFR could predict PPCs.[5] Stein et al found that 66% of patients with abnormal preoperative pulmonary function developed PPCs, and PEFR was the best spirometric test to predict PPCs.[8] Gass et al., found marked alterations in diaphragmatic excursion, and marked changes in regional ventilation with a shift of ventilation from the bases of the lung to the apices and restriction of lung expansion at the bases after abdominal surgery.[9] Thus preoperative pulmonary function testing could predict PPCs.

A few studies about the utility of spirometry before abdominal operations have reached conflicting conclusions. Studies concluding that spirometry is predictive of PPCs rely on univariate analysis without adequate adjustment for potential confounding risk factors.[10,1]1 A critical review concludes that preoperative spirometry is not useful in predicting PPCs after abdominal operation.[12] Arozullah et al., developed a risk index for predicting PPCs, but spirometry values are not included in that risk index.[13] Another study examined the relationship between preoperative respiratory symptoms and pulmonary function test, and post-operation risk of severe respiratory complications.[14] They found pulmonary function test could predict PPCs, and they developed an equation for calculating the probability of predicted pulmonary complications. Its sensitivity was 84% and specificity was 99%. There are many limitations of both risk indexes because there are more than 20 clinical variables that are used to calculate the risk index of Arozullah,[13] and another equation[14] needs complicated instruments to obtained spirometric variables. Therefore, they cannot be used clinically to predict risk.

The aims of this study were to determine the association between PEFR and PPCs, and to develop a simple, reliable diagnostic model to predict PPCs.

MATERIALS AND METHODS

The target population was patients undergoing a scheduled elective abdominal surgical procedure at the Department of Surgery, Faculty of Medicine at Siriraj Hospital between 1 September 2003 and 31 August 2004. Inclusion criteria were as follows: scheduled for non-laparoscopic elective procedure under general anesthesia with intubation or mask; anticipated post-operation stay of at least 48 hr; extubation in 24 hours after operation finished; age between 15 and 85 years old and able to understand informed consent. Subjects were excluded for the following reasons: underlying and preoperative evidence of pulmonary diseases, ischemic heart disease, vulvular heart disease and significant arrhythmia (second, third degree atrioventricular block and supraventricular tachycardia with fast ventricular response); previous lung, thoracic and cardiac surgery; and reintubated in 24 hours after operation finished. The study was approved by the institutional committee on human research at the Siriraj Hospital and informed consent was obtained.

PPCs were defined as pneumonia, atelectasis, tracheobronchitis, respiratory failure, pleural effusion and pneumothorax. The criteria for PPCs had previously been described elsewhere.[4,13] Investigators were not involved with clinical care of the patients.

In the preoperative setting, information was obtained via interview regarding demographic and preoperative risk factors. The patients were measured peak expiratory flow rate (PEFR) using Mini-Wright Peak Flow Meter (Clement Clarke®) by well-trained investigators in supine position with the head of the bed elevated 30 degrees before operation. The highest value of three attempts was collected. On post-operation days 1 through 7, the patients were seen daily and data collection included a short interview, review of the medical record, and PEFR was measured by the same technique as pre-operation. If the patients remained in the hospital for greater than 7 days, the medical chart was reviewed on a daily basis, but PEFR was not measured.

Statistical analysis

Data were analyzed using a software package (SPSS 11.0; SPSS; Chicago). Summary descriptive statistics were computed for all variables and included frequencies, proportions, means and SDs. Correlations for risk factors and PPCs were analyzed using the t test, x^2 test and Fisher's Exact Test. Using logistic regression,

models were developed in several steps to predict the development of PPCs. A forward stepwise logistic approach was used with p≤0.05 as a limit for entering new variables. The analysis yielded a discriminant equation showing the relation between the discriminant score (PEFR Score) and the independent variables. The discriminant equation may be written as: $W = a + b_1X_1 + b_2X_2 + \ldots + b_pX_p$, where W = discriminate score, a = constant, b_i = discriminant coefficient (i = 1,2,3,…p), and X_i = independent variable. W was labeled as the PEFR score. To assess goodness of fit, the Hosmer-Lemeshow statistic was calculated. An insignificant p value (p≥0.05) for this test statistic indicated that the model was robust over the range of predicted probabilities. The receiver operator characteristic (ROC) statistic was also calculated. The ROC described the continuous trade-off between sensitivity and specificity, and ranged from 0.5 for random noise (a model no better than chance) to 1.0.

RESULTS

Of the 156 patients initially enrolled into the study, 5 were excluded due to post-operation intubation more than 24 hours. Thus, 151 patients were available for model building. Of this, 15 (9.9%) developed PPCs as follows: pneumonia, 3 (2%); atelectasis, 7 (4.6%); tracheobronchitis, 1 (0.7%); respiratory failure, 2 (1.3%); pleural effusion, 1(0.7%); pneumothorax, 1 (0.7%).

Demographics and clinical characteristics have been shown in Table 1. An initial univariate analysis was made of all clinical variables, but only malignancy (p=0.012) and in-hospital mortality (p=0.000) were statistically significantly associated with PPCs. Preoperative Peak Expiratory Flow Rate (PrePEFR) and daily post-operation PEFR in the PPCs group were statistically significantly decreased as shown in Fig 1. Two risk factors with significant p value were submitted to multivariate logistic regression analysis and those factors were statistically significant throughout the process. These were malignancy, and 24 hours post-operation peak expiratory flow rate (PostPEFR). The results of the two-factor risk model have been shown in Table 2. The discriminant equation (PEFR Score) was obtained by multiplying the β–coefficients from the logistic regression model by 10 in order to achieve more rounded numbers. The equation has been shown in Fig 2. Fig 3 has shown the relationship between the discriminant function value and the calculated probability of PPCs. The PEFR Score was plotted on an ROC curve (Fig 4), and it was noted that a score of -4.68 is of the most diagnostic value. The sensitivity of the score to detect PPCs was 80% and specificity was 73.5% (Table 3).

DISCUSSION

The overall incidence of post-operation pulmonary complications (PPCs) following abdominal surgery is approximately 10%[1]; although estimations vary widely in the literature (10 to 69%).[1,2] This variability is due primarily to the type of PPCs studied, and clinical criteria used in the definition. In this study, the incidence of PPCs was 9.9% using multiple definitions for atelectasis, pneumonia, tracheobrochitis, pleural effusion and pneumothorax. Many risk factors have proven to be predictors of pulmonary complications such as underlying pulmonary and cardiovascular diseases, preoperative sputum production, age, history of cancer, American Society of Anesthesiologists Score more than 2, site of surgical incision and nasogastric tube placement[4,5,15] The result of this study was not consistent with the literature, and the diagnosis of cancer was the only risk factor that was significantly associated with PPCs. The difference of the result may be related to the populations, because patients who had underlying heart and lung diseases were excluded. Only upper abdomen or long midline incision were included in this study.

Patients with PPCs have significant increase in hospital mortality, and more hospital length of stay than patients without PPCs. Thus surgeons should have diagnostic tools for early detection and prophylaxis for this problem. Previous post-operation pneumonia risk indexes[13] have multiple clinical variables, thus they were complicated to use. This study paid attention to the role of preoperative and post-operation changes of peak expiratory flow rate (PEFR) for early

TABLE 1. Demographic and Clinical Characteristics of Patients with and without Post-operative Pulmonary Complications (PPCs).

| Patient demographics and clinical characteristics	Patients with PPCs (n=15)	Patients without PPCs (n=136)	p-value
Age <60 yr, n (%)	8 (53.3)	93 (68.4)	0.258
≥60 yr	7 (46.7)	43 (31.6)	
Male, n (%)	9 (60)	65 (47.8)	0.423
Presence of comorbidity, n (%)	6 (40)	43 (31.6)	0.565
ASA category, n (%)			0.117
Class 1	2 (13.3)	49 (36)	
Class 2	11 (73.3)	80 (58.8)	
Class 3	2 (13.3)	7 (5.1)	
Functional status, n (%)			0.398
>10 METs	1 (6.6)	18 (13.2)	
4-10 METs	13 (86.7)	115 (84.6)	
1-4 METs	1 (6.6)	3 (2.2)	
Type of procedure, n (%)			0.749
Gastric and duodena	2 (13.3)	25 (18.3)	
Hepatobiliary	8 (53.3)	51 (37.5)	
Pancreatic	2 (13.3)	11 (8)	
Small bowel	3 (20)	22 (16.2)	
Colonic	0	16 (11.8)	
Splenic	0	6 (4.4)	
Abdominal wall	0	4 (2.9)	
Aortic	0	1 (0.7)	
Type of anesthesia, n (%)			0.346
General anesthesia with intubation	4 (26.7)	59 (43.4)	
General anesthesia with mask	0	1 (0.7)	
General anesthesia combined with epidural block	11 (73.3)	76 (55.9)	
Nasogastric tube placement, n (%)	11 (73.3)	73 (53.7)	0.178
Malignant diseases, n (%)	13 (86.7)	70 (51.5)	0.012*
Smoking, No. (%)			0.566
Nonsmoking	7 (46.7)	81 (59.6)	
Stop 2 weeks prior	6 (40)	40 (29.4)	
Current smoking	2 (13.3)	15 (11)	
Blood transfusion >4 unit, n (%)	2 (13.3)	4 (3.3)	0.110
In-hospital mortality, n (%)	5 (33.3)	2 (1.4)	<0.001
BMI (kg/m^2)	21.7±3.4	22.3±3.9	0.270
Length of stay (days)	27.5	14.8	0.056
Anesthetic time (minutes)	193.3±81.2	175.4±90.2	0.463

Values are presented as n (%), mean ± SD, significant as p<0.05

METs, Metabolic equivalent task

*Statistically significant difference
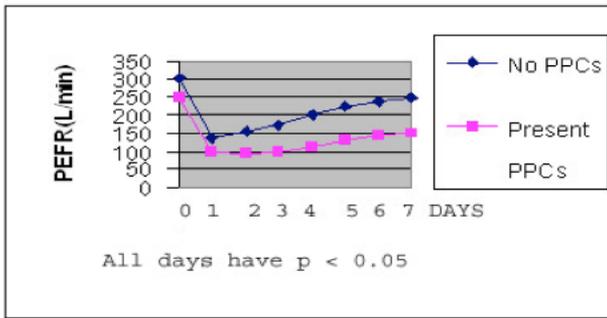
**Fig 1.** Mean pre-operative and post-operative PEFR.
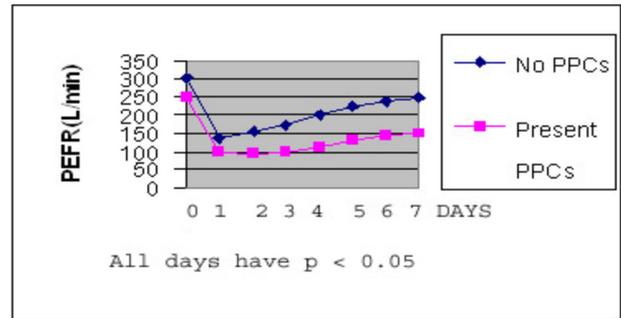

Fig 2. The discriminant equation.

PEFR Score = (17.24 x Malignant) - (0.16 x PostPEFR)

Malignant : 1 = malignancy, 0 = benign

PostPEFR : 24 hours Post-operative Peak Expiratory Flow Rate (L/min)

detection of PPCs. Preoperative PEFR and daily post-operation PEFR have significant decreases in patient with PPCs. The PPCs especially post-operation pneumonia commonly occurr in the third to sixth post-operation days 16, thus 24 hours post-operation PEFR (PostPEFR) was analysed using logistic regression analysis. The PEFR Score is obtained by calculating two clinical variables, the cut off points were set at -4.68. It had an overall predictive accuracy of 74.2% and sensitivity 80%. Gracey, et al reported on the role of preoperative spirometry for predicting post-operation pulmonary complications especially in chronic obstructive pulmonary disease patients.[17] However, a spirometer is unavailable in many hospitals, thus this study used peak flow meter which was cheaper and available for bedside measurement. Advantages of PEFR Score are that the variables needed to calculate it are readily accessible for almost all patients undergoing major surgery and that it can be calculated at the bedside without expensive preoperative testing.

This study has several limitations. This model is suitable for fair to good functional status patients, because the majority of the subjects in
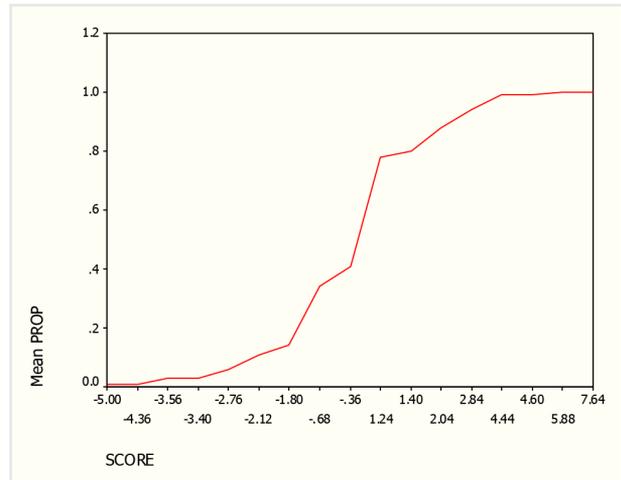
Fig 3. The relationship between probability of PPCs and PEFR Score.
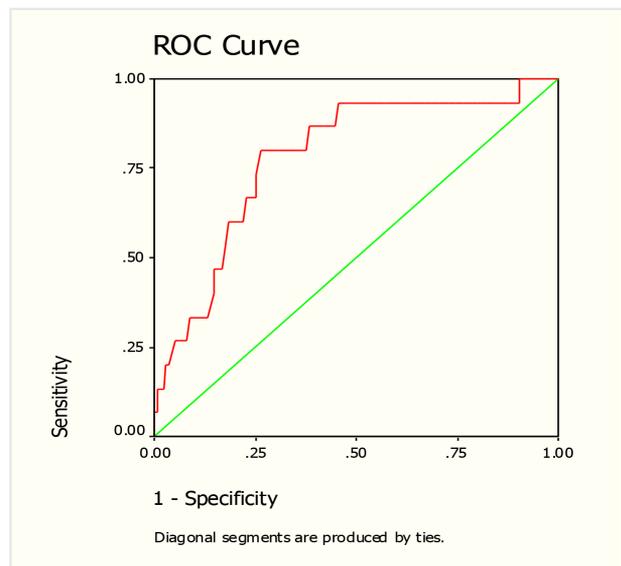
Fig 4. ROC curve of PEFR Score.

TABLE 2. Logistic regression - two factor risk model.

Variable	β-coefficients	SE	p value
Malignant diseases	1.724	0.788	0.029
PostPEFR	-0.016	0.007	0.017
Constant	-1.563	1.011	0.122

24 hrs Post-operative Peak Expiratory Flow Rate (PEFR)

TABLE 3. Sensitivity and specificity of peak expiratore flow rate (PEFR) Score.

PEFR Score	Patients with PPCs (n=15)	Patients without PPCs (n=136)
< - 4.68	3	100
≥ - 4.68	12	36

Sensitivity for detect PPCs (≥-4.68): (12/15) x 100 = 80 %
Specificity for detect PPCs (≥-4.68): (100/136) x 100 = 73.5%
Accuracy: (112/151) x 100 = 74.2%

this study did have not serious comorbid illness, and all subjects were schedule for elective surgery, so if they had comorbid illness, it was well controlled. The incidence of PPCs was underestimated because investigators were not involved with clinical care of the patients and post-operation chest radiographs or sputum cultures were not performed for all patients. However many self limited post-operation pulmonary problems especially atelectasis were not classified in the PPCs group because they did not fulfill the criteria for diagnosis of PPCs. This study is only a prospective study, so it needs further validation study to confirm accuracy and sensitivity for detecting PPCs.

REFERENCES

1. Wirén JE, Janzon L, Hellekant C. Respiratory complications after upper abdominal surgery. The incidence of chest X-ray abnormalities, arterial hypoxemia and clinically recorded pulmonary complications. Acta Chir Scand. 1981; 147(8):623-7.
2. Hall JC, Tarala RA, Hall JL, Mander J. A multivariate analysis of the risk of pulmonary complications after laparotomy. Chest. 1991 Apr;99(4):923-7.
3. Calligaro KD, Azurin DJ, Dougherty MJ, Dandora R, Bajgier SM, Simper S, et al. Pulmonary risk factors of elective abdominal aortic surgery. J Vasc Surg. 1993 Dec; 18(6):914-20.
4. Lawrence VA, Dhanda R, Hilsenbeck SG, Page CP. Risk of pulmonary complications after elective surgery. Chest. 1996 Sep;110(3):744-50.
5. Fisher BW, Majumdar SR, McAlister FA. Predicting pulmonary complications after nonthoracic surgery:a systematic review of blinded studies. Am J Med. 2002 Feb 15;112(3):219-25.
6. Hasukic S, Mesic D, Dizdarevic E, Keser D, Hadziselimovic S, Bazardzanovic M. Pulmonary function after laparoscopic and open cholecystectomy. Surg Endosc. 2002 Jan;16(1): 163-5.
7. Stock MC, Downs JB, Gaucer PK, Alster JM, Imerey PB. Prevention of post-operation pulmonary complications with CPAP, incentive spirometry, and conservative therapy. Chest. 1985 Feb;87(2):151-7.
8. Stein M, Koota GM, Simon M, Frank HA. Pulmonary evaluation of surgical patients. JAMA. 1962 Sep 1;181: 765-70.
9. Gass GD, Olsen GN. Preoperative pulmonary function testing to predict post-operation morbidity and mortality. Chest. 1986 Jan;89(1):127-35.
10. Kispert JF, Kazmers A, Roitman L. Preoperative spirometry predicts perioperative pulmonary complications after major vascular surgery. Am Surg. 1992 Aug;58(8):491-5.
11. Wittgen CM, Naunheim KS, Andrus CH, Kaminski DL. Preoperative pulmonary function evaluation for laparoscopic cholecystectomy. Arch Surg. 1993 Aug;128(8): 880-5.
12. Lawrence VA, Page CP, Harris GD. Preoperative spirometry before abdominal operations. A critical appraisal of its predictive value. Arch Intern Med. 1989 Feb;149(2): 280-5.
13. Arozullah AM, Khuri SF, Henderson WG, Daley J. Development and validation of a multifactorial risk index for predicting post-operation pneumonia after major non-cardiac surgery. Ann Intern Med. 2001 Nov 20;135(10): 847-57.
14. Barisione G, Rovida S, Gazzaniga GM, Fontana L. Upper abdominal surgery: does a lung function test exist to predict early severe post-operation respiratory complications. Eur Respir J. 1997 Jun;10(6):1301-8.
15. Brooks-Brunn JA. Predictors of post-operation pulmonary complications following abdominal surgery. Chest. 1997;111: 564-7.
16. 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 Oct;114(4):815-9.
17. Gracey DR, Divertie MB, Didier EP. Preoperative pulmonary preparation of patients with chronic obstructive pulmonary disease: a prospective study. Chest. 1979 Aug;76 (2):123-9.