Preoperative Prediction of Pulmonary Complications Following Thoracic Surgery


The ability of preoperative quality-of-life and physiologic variables to predict postoperative complications was tested in 117 consecutive patients undergoing thoracotomy for possible or definite lung cancer. Preoperatively, quality of life was globally assessed by the QLI and Sickness Impact Profile. Dyspnea was assessed by the Clinical Dyspnea Index and a modified Pneumoconiosis Research Unit question. Spirometry and maximal exercise testing were carried out in 115 and 46 subjects, respectively. Thirty-seven percent experienced at least one respiratory complication (eg, pneumonia, atelectasis prompting bronchoscopy, pulmonary embolism). Twofold or greater increases in respiratory complications were associated with current smoking (p<0.05), cancer as the final pathologic condition (p<0.05), at least moderate dyspnea (p<0.10), FEV₁, <60 percent of predicted (p<0.05), ventilatory reserve <25 L (p<0.05), and VO₂max <1.25 L (p<0.05). Twofold increases in the incidence of any complication (respiratory, cardiac, etc) were associated with age ≥75 years (p<0.05) and cancer as the final pathologic condition (p<0.05). We conclude that simple historic information (age, smoking status, cancer status, dyspnea) indicates the risk of postoperative morbidity. General quality-of-life measures were not good predictors of morbidity. Our findings corroborate the few studies supporting the value of VO₂max and suggest that the usefulness of the ventilatory reserve deserves further attention. (Chest 1993; 104:155-59)

CDI = Clinical Dyspnea Index; PRU = Pneumoconiosis Research Unit Index; QLI = Quality of Life Index; SIP = Sickness Impact Profile

In North America, carcinoma of the lung is the most common cause of death due to cancer in men and the second most common in women.¹ Statistics Canada estimates that lung cancer will cause approximately 14,200 deaths and 17,300 new cases will arise in 1991.¹ Candidates for surgical treatment are those with stage I and II disease, and a limited group with stage III in whom a complete resection is envisaged.² Ginsberg et al³ reported postoperative mortalities of 7.7 percent for pneumonectomy and 3.3 percent for lobectomy. Male sex, older age, greater extent of surgical resection, and a reduced 1-s forced expired volume (FEV₁) have been associated with increased postoperative morbidity and mortality in most but not all studies.³⁻²⁰

The predictive value of preoperative FEV₁ is the most controversial with only 7 of 12 studies reporting significant (p<0.05) associations.⁴⁻¹⁰,¹²,¹⁴⁻¹⁷ Exercise capacity has been associated with postoperative complications, but the clinical usefulness of this test is controversial.²¹ Further research has been recommended because the studies are few in number, use different populations, measure exercise capacity by different methods, and results have been inconsistent with five of nine studies showing a statistical association of p<0.05.¹⁰,¹¹,¹³,¹⁴,¹⁸,²¹⁻²⁴

Preoperative quality of life has not been tested previously as a predictor of postoperative complications. Quality of life, “that which makes life worth living,” reflects impairment, disability, and handicap along physical, emotional, and social dimensions.²⁵

To address these issues, the present study assesses relations between postoperative complications and preoperative factors, including quality of life, spirometry, and exercise endurance.

Accurate prediction of postoperative morbidity would improve patient selection for thoracotomy as well as assist in counseling patients about operative risks.

METHODS

Study Population

Eligible subjects were those scheduled to undergo thoracotomy for possible or definite lung cancer between December 1987 and December 1989. From two University of Ottawa teaching hospitals, subjects were sought through computerized hospital admission records updated on a daily basis, and weekly phone calls to the respiratory medicine and thoracic surgery physicians. Subjects who gave written consent to participate in the study were interviewed preoperatively to assess quality of life. They were also submitted to pulmonary function and exercise testing approximately 1 week before thoracotomy.

All operations were performed by one of four surgeons, and postoperative care was supervised on a thoracic surgical ward or if necessary in an ICU. Hospital records were reviewed to identify postthoracotomy complications occurring in the hospital admission during which the thoracotomy has been performed.

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Quality-of-Life Measures

Approximately 1 week prior to surgery, the following questionnaires were administered at the bedside by a nurse trained in interviewing techniques.

Measures of Perceived Dyspnea: The Clinical Dyspnea Index (CDI), a reproducible and easily administered questionnaire, was used to assess dyspnea in terms of functional impairment and magnitude of task or effort. The CDI results have correlated well with objective measures of respiratory impairment. The Pneumonitis Research Unit Index (PRU) is a simple index that has been widely used in modified form in the British Medical Research Council and American Thoracic Society questionnaire.

Measures of Perceived Overall Functioning: The Quality of Life Index (QLI) is composed of five components: "Activity" refers to working, studying, managing own household, and voluntary activities. "Daily living" encompasses eating, bathing, toileting, dressing, and the use of transportation facilities. "Health" concerns feelings of well-being. "Support" includes social support from family and friends, while "outlook" reflects such feelings as anxiety, confusion, depression, and the degree of control over personal life. Spitzer et al. reported acceptable validity in cancer patients. The Sickness Impact Profile (SIP) is a general quality-of-life indicator that includes various aspects of life such as sleep and rest, eating, work, home management, recreation and hobbies, ambulation, mobility, body care, social interaction, and behavior. A standardized assessment of health status, it has been applied to study disabling illnesses and its reliability and validity are documented.

Physiologic Measures

Spirometry was performed according to established guidelines. Variables used in analyses were the FEV, and forced vital capacity (FVC). Exercise capacity was determined by a multistage incremental protocol with breath-by-breath measurement and gas exchange analysis. A portable microprocessor-controlled metabolic cart (Sensor Medics MMC Horizon) was interfaced with a treadmill (Marquette Electronics) and 12-lead ECG. Calibration was done on the day of the test. The treadmill was set at the maximum speed comfortable for each patient with no incline (1 to 4 km/h). The angle of the treadmill was then increased by 2° every 2 min until maximal exertion was perceived, and despite encouragement, the subject could not continue. Variables used in the study were maximum oxygen consumption (VOmax), percentage of predicted maximum minute ventilation (Vemax percent) calculated by Vemax observed = (observed FEV1 x 35), and ventilatory reserve calculated as 35 x observed FEV1 - observed Vemax.

Postoperative Complications

All hospital charts were reviewed for extent of surgery, final pathologic condition, and complications. Complications were defined a priori in a comprehensive list and grouped as follows.

General complications included (1) at least 21 days between the dates of surgery and hospital discharge, (2) ICU stay of at least 3 days, and (3) death.

Respiratory complications included (1) atelectasis prompting bronchoscopy; (2) pneumonia defined by a radiographic infiltrate plus at least two of the following: temperature >37.7°C, white blood cell count >10,500/mm³, initiation of antibiotics therapy, and demonstration of pathogenic organisms; (3) PaCO2 >50 mm Hg at 24 h; (4) air leak or effusion requiring intercostal tube drainage for more than 7 days; (5) bronchopleural fistula; (6) empyema; (7) chylothorax; (8) hemotherax requiring drainage or reoperation; (9) tension pneumothorax; (10) pulmonary embolism; (11) lobar gangrene; (12) mechanical ventilation ≥72 h for any reason; (13) intercostal tube drainage ≥14 days for any reason; and (14) required FiO2 ≥0.6 or alveolar-arterial oxygen gradient ≥300 mm Hg 24 h postoperatively.

Cardiac complications included (1) myocardial infarct defined by new-onset "Q" waves or elevated CK-MB fraction, (2) arrhythmia requiring treatment, and (3) congestive heart failure defined by bilateral crackles, radiographic changes, or elevated pulmonary artery wedge pressure and requiring therapy.

Other complications were (1) renal failure requiring dialysis, (2) cerebrovascular accident, (3) gastrointestinal bleeding, and (4) wound infection.

Statistical Analyses

Data were entered, cleaned, and summarized using the Statistical Analysis System (SAS). Continuous data were expressed categorically to demonstrate predictive values, the relevant statistics for clinical decisions. Cuts-points were chosen to reflect extreme values while at the same time ensuring at least five counts were in each cell of the contingency table. Categorization, however, resulted in a loss of statistical power to detect associations between perioperative complications and preoperative host factors. χ² testing was used to test for statistical significance.

RESULTS

Two hundred ninety-seven patients were admitted to the hospital during the study period with a possible or definite diagnosis of lung cancer. Nineteen declined surgery, and 100 were determined to have inoperable or unresectable disease prior to thoracotomy. Of the remaining 178 eligible patients, 29 refused to participate and 32 could not be interviewed prior to surgery. One hundred seventeen patients comprised the study group. Quality-of-life questionnaires were completed in 117, and spirometry was performed in 115. Exercise testing was done in 46 patients. No subject was excluded or included a priori from exercise testing. It was often not possible to schedule patients prior to surgery due to limitations of time and resources. Eighteen patients underwent pneumonectomy, 86 lobectomy, 2 wedge resection, and 11 thoracotomy without lung resection (Table 1). Ninety-one patients had a postoperative diagnosis of cancer. Postoperative complications were experienced in 27 percent of thoracotomies, 47 percent of lobectomies, and 56 percent of pneumonectomies (Table 1). The only death occurred in the pneumonectomy group. Respiratory complications occurred in 37 percent of subjects, cardiac complications in 13 percent, and at least one (any complications) occurred in 46 percent.

To assess the possibility of selection bias, complications were contrasted between those with and without exercise test data. The incidence of all complications was 46 percent in both groups. Respiratory complications, in particular, occurred in 33 percent of those with and 39 percent of those without a measured VOmax indicating no significant selection bias.

The percentage of complications increased with age (Table 2). Those at least 75 years of age had twice as many complications as those younger than 50 years of age. Complications were approximately 50 percent less among those with a body mass index greater than 30 compared with less than 20. Current cigarette smoking and the presence of lung cancer at final
cardiac and respiratory complications were each associated with a doubling of the complication rate (p<0.05). There was little difference in the rate of complications between male and female subjects. 

Of all the quality-of-life measures, the Simple Pneumonicon Research Unit questions concerning dyspnea best predicted postoperative complications (Table 3). Those who were “unable to walk more than 100 yards on the level without a rest” or “breathless on talking, dressing, or unable to leave the house because of breathlessness” had a complication rate of 53 percent, approximately double that of the group with no abnormal dyspnea (p<0.10). The CDI, composed of function, magnitude of task, and magnitude of effort, did not discriminate particularly well. There was a nonsignificant trend toward poor scores on the global quality-of-life indices being associated with increased respiratory complications.

As shown in Table 4, the preoperative physiologic variables showed stronger statistical associations with postoperative complications than did the aforementioned quality-of-life variables. This was true despite the smaller number of patients who underwent physiologic testing. The incidence of respiratory complications was only 21 percent among those with a normal FEV$_1$ compared with 50 percent among those with an FEV$_1$ less than 60 percent of predicted (p<0.05). The same trend was seen with all complications but it was not statistically significant. A doubling of the complication rate was also seen in those within FVC less than 60 percent compared with greater than 80 percent of predicted.

In contrast to the percentage of predicted FEV$_1$, the absolute value of FEV$_1$ was not significantly associated with pulmonary complications (values not shown). Both a high observed $\bar{V}_{\text{Emax}}$ percent and a low ventilatory reserve were associated with respiratory but not all complications (p<0.05 for ventilatory reserve). Complication rates were two and a half times higher among those with a lower compared with a higher $O_{\text{max}}$ measured in milliliters per minute. The $O_{\text{max}}$ expressed as a percentage of predicted was not as accurate at identifying complications.

In summary, twofold to threefold increases in respiratory complications were identified by current smoking status, final pathologic condition being cancer, dyspnea with minimal exertion (PRU), the percentage of predicted FEV$_1$, $\bar{V}_{\text{Emax}}$ percent, ventilatory reserve, and $O_{\text{max}}$. Twofold increases in the incidence of all complications were associated with older age, current cigarette smoking, and final pathologic condition being lung cancer.

For combinations of factors, complication rates were as follows: 57 percent for a current smoker with a final diagnosis of lung cancer (p = 0.03); 48 percent with a predicted FEV$_1$ <80 percent and ventilatory reserve <25 L (p = 0.006); and 50 percent with a predicted FEV$_1$ <80 percent and $O_{\text{max}}$ <1,250 ml (p = 0.002).

**DISCUSSION**

The present study demonstrates that several preoperative factors are associated with twofold to threefold increase in postoperative respiratory complications. The study confirms that the traditionally used FEV$_1$ is one of the better indicators of postoperative complications. The findings also support the few studies of $O_{\text{max}}$ that found it to be an important predictor of postoperative complications. In addition,
we found that ventilatory reserve at maximal exercise was as useful as the $V_{O_2}$max. The a priori reason for testing ventilatory reserve was that those who already have a respiratory limitation to exercise would be expected to show more deterioration following removal of lung tissue than those whose exercise endurance ($V_{O_2}$max) was limited by cardiac or musculoskeletal disease. Our findings support this hypothesis, but verification requires confirmation in further studies. A simple dyspnea index, modified from the PRU questionnaire, better predicted complications than other more detailed dyspnea questions. For all quality-of-life indicators, however, conventional levels of statistical significance ($p<0.05$) were not obtained, although twofold differences in postoperative complications were detected by these measures. This apparent contradiction can be explained by a high degree of incorrect classification (or inaccuracy) inherent to these questions.

The synthesis of these observations would be that respiratory impairment preoperatively measured by dyspnea, $FEV_1$, and ventilatory limitation is predictive of postoperative respiratory complications. The previously observed association between $V_{O_2}$max and respiratory complications may be due to respiratory limitation because $V_{O_2}$max but not HRmax was also associated with complications.

Statistically significant associations between preoperative variable and postoperative complications are not equivalent to high predictive ability. There was a great deal of overlap in the $FEV_1$ distributions between those with and without complications indicating that incorrect risk classification of individual patients occurs. This is to be expected a priori because no one variable would be expected to accurately predict atelectasis, pneumonia, and persistent airleaks that are likely multifactorial in nature. This is one reason why controversy probably exists in the literature regarding the inability to predict preoperative complications. The truth probably lies somewhere in between as indicated by our studies where the twofold to threefold increase in risks does not equate to accurate classification on an individual basis. Part of the reason why we may have found significant differences, when others did not, was our study methodology. We separated respiratory from all other complications because different complications have different underlying causes. For example, $FEV_1$ better predicted respiratory than all complications. We also chose important complications. Atelectasis comprises the majority of complications in many studies that overwhelm other complications. In our study, we chose only the 3 cases of atelectasis that prompted bronchoscopy, although there were approximately 30 other cases where it was noted on radiograph but was not otherwise clinically significant.

Easily obtainable information such as age, smoking history, level of dyspnea, $FEV_1$, and extent of proposed

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**Table 3—Probability of Developing Postoperative Complications by Preoperative Quality-of-Life Scores**

<table>
<thead>
<tr>
<th>Quality of Life</th>
<th>Degree of Impairment</th>
<th>Respiratory, %</th>
<th>All Complications, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dyspnea indices</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pneumoconiosis Research Unit</td>
<td>None (n = 33)</td>
<td>28</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>≥Moderate (n = 15)</td>
<td>53</td>
<td>53</td>
</tr>
<tr>
<td>Clinical Dyspnea Index</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Function</td>
<td>None (n = 67)</td>
<td>37</td>
<td>46</td>
</tr>
<tr>
<td></td>
<td>≥Moderate (n = 10)</td>
<td>40</td>
<td>50</td>
</tr>
<tr>
<td>Task</td>
<td>None (n = 64)</td>
<td>31</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>≥Moderate (n = 44)</td>
<td>43</td>
<td>48</td>
</tr>
<tr>
<td>Effort</td>
<td>None (n = 51)</td>
<td>36</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td>≥Moderate (n = 44)</td>
<td>33</td>
<td>37</td>
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<tr>
<td>Global indices</td>
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<td></td>
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<tr>
<td>QLI</td>
<td>None (n = 86)</td>
<td>34</td>
<td>44</td>
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<tr>
<td></td>
<td>≥Moderate (n = 29)</td>
<td>45</td>
<td>52</td>
</tr>
<tr>
<td>SIP</td>
<td>None (n = 86)</td>
<td>34</td>
<td>44</td>
</tr>
<tr>
<td></td>
<td>≥Moderate (n = 29)</td>
<td>45</td>
<td>52</td>
</tr>
</tbody>
</table>

*QLI = quality of life index; SIP = sickness impact profile.

**Table 4—Probability of Developing Postoperative Complications by Preoperative Physiologic Variables**

<table>
<thead>
<tr>
<th>Physiologic Variables</th>
<th>All Complications, %</th>
<th>Respiratory</th>
<th>All Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>$FEV_1$</td>
<td>≥80 (n = 43)</td>
<td>21*</td>
<td>37</td>
</tr>
<tr>
<td>% predicted</td>
<td>&lt;80 (n = 50)</td>
<td>50</td>
<td>58</td>
</tr>
<tr>
<td>$FVC$</td>
<td>≥80 (n = 70)</td>
<td>33</td>
<td>44</td>
</tr>
<tr>
<td>% predicted</td>
<td>&lt;80 (n = 10)</td>
<td>60</td>
<td>70</td>
</tr>
<tr>
<td>$V_{O_2}$max</td>
<td>≥70 (n = 53)</td>
<td>24*</td>
<td>39</td>
</tr>
<tr>
<td>% predicted</td>
<td>≥70 (n = 16)</td>
<td>50</td>
<td>63</td>
</tr>
<tr>
<td>Ventilatory reserve, L</td>
<td>≥25 (n = 9)</td>
<td>21*</td>
<td>39</td>
</tr>
<tr>
<td>$V_{O_2}$max, ml</td>
<td>≥1250 (n = 26)</td>
<td>19*</td>
<td>38</td>
</tr>
<tr>
<td>% predicted</td>
<td>≤1250 (n = 20)</td>
<td>50</td>
<td>55</td>
</tr>
<tr>
<td>$V_{O_2}$max</td>
<td>≥80 (n = 19)</td>
<td>37</td>
<td>58</td>
</tr>
<tr>
<td>% predicted</td>
<td>≤80 (n = 27)</td>
<td>30</td>
<td>37</td>
</tr>
</tbody>
</table>

*p≤0.05 Fisher's Exact Test.
surgery are associated with perioperative complications. This can be supplemented by exercise testing variables. General quality-of-life assessments appear to be too inaccurate for this purpose.

REFERENCES