Cardiopulmonary Risk Index Does Not Predict Complications After Thoracic Surgery*

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Study objective: The preoperative cardiopulmonary risk index (CPRI) is a multifactorial index intended to predict postoperative outcome after thoracic surgery. It combines cardiac and pulmonary information into one parameter that ranges from 1 to 10, with 10 being the worst. A CPRI ≥4 has been advocated as an effective predictor of postoperative pulmonary and cardiac complications. This study prospectively evaluates the predictive value of CPRI in a large population of patients undergoing thoracic surgery.

Design: We performed prospective calculation of CPRI in patients about to undergo thoracic surgery. Postthoracic surgery occurrence of pneumonia, atelectasis, arrhythmias, congestive heart failure, respiratory failure requiring therapy, or death occurring within 30 days of surgery was compared with preoperative CPRI and its components.

Patients and participants: One hundred eighty consecutive patients, aged 15 to 87 years, were studied.

Interventions: Operations performed included 114 lobectomies, 35 wedge resections, 19 pneumonectomies, 5 pleurectomies, 5 lymph node dissections, 1 thoracic wall resection, and 1 paravertebral tumor resection.

Measurements and results: Twenty-seven percent of patients experienced complications. CPRI and its components did not predict complications, deaths, or the number of in-hospital days. We found a CPRI ≥4 to be a moderate predictor of outcome for patients undergoing pneumonectomy (n=19). It correctly identified four of nine postpneumonectomy complications.

Conclusion: The preoperative CPRI and its components are inadequate predictors of medical complications after thoracic surgery in a general population. In the subgroup of patients undergoing pneumonectomy, the index may be of some value in forecasting outcome.

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Key words: outcome; postoperative complications; prediction; thoracic surgery

Abbreviations: CHF = congestive heart failure; CPRI = cardiopulmonary risk index; CRI = cardiac risk index; NPA = negative predictive accuracy; PPA = positive predictive accuracy; PRI = pulmonary risk index; ROC = receiver operating characteristic curve

Clinicians have sought an estimate, before surgery, of the postoperative risk of morbidity and mortality after lung resection.1-5 Historically, appraisal of operability has been performed with the aid of spirometry,6-11 blood gas analysis,12,13 split lung function,14,16 and measurement of pulmonary vascular resistance.15,17,18 None of those variables, however, has proved to be a sufficiently reliable predictor of outcome. Exercise testing and measures of oxygen consumption during exercise have recently generated substantial research interest.13,15,16,19-26 Investigators have postulated that exercise mimics the postoperative stress conditions present after thoracic surgery, thereby providing a window into postresectional pulmonary function. The predictive power of these techniques has also been insufficiently accurate.

Recently, Epstein et al27 have advocated the use of a multifactorial cardiopulmonary risk index (CPRI) to predict outcome after thoracic surgery. The CPRI is the arithmetic addition of the Goldman criteria index,25 modified using echocardiographic or gated pool scanning ejection fraction data, plus the pulmonary risk index (PRI) created by assigning a value of 1 to each of six variables, shown by univariate analysis to correlate with outcome: obesity, cough, elevated PaCO₂, poor spirometric performance, re-
cent cigarette smoking, and diffuse wheezing. The total range of CPRI is from 1 to 10 points, with 10 being the worst. An adverse outcome is defined by postoperative complications occurring within 30 days of surgery and requiring therapy. Using this technique, Epstein et al. \(^{27}\) studied 42 patients and showed that a CPRI \(\geq 4\) was highly predictive of complications. In a subsequent study on an additional 32 patients, Epstein et al. \(^{29}\) provided evidence supporting the use of the combination of a CPRI \(\geq 4\) and poor exercise performance as a predictor of adverse outcome. \(^{29}\) Patients with a CPRI \(\geq 4\) who were unable to undergo preoperative exercise testing because of limitations by musculoskeletal, neurologic, peripheral vascular, or psychiatric disease experienced the highest incidence of postoperative complications.

In an attempt to prospectively validate the predictive power of the CPRI and to derive a more accurate index by weighing the individual pulmonary factors, we scored 180 patients scheduled for thoracic surgery and followed their postoperative course. We compared predicted outcome as determined by the CPRI with 30-day actual outcome.

**Materials and Methods**

After institutional review board approval, prospective preoperative data were collected for CPRI calculations in 180 consecutive patients between July 1994 and January 1995. The surgery was performed by different, but comparatorably experienced surgeons. Those patients who underwent more complex operations than a wedge resection remained in the recovery room overnight following surgery. When in stable condition, patients were transferred to a specialized thoracic unit where they remained until hospital discharge, receiving uniform postoperative care.

**Preoperative Evaluation**

All patients had a complete history and physical examination on admission to the hospital and underwent spirometric tests and ECGs prior to surgery. The evaluated preoperative cardiac risk index (CRI) parameters included the presence of congestive heart failure (CHF) evaluated with echocardiography or gated pool scanning, myocardial infarction occurring within 6 months, ECG abnormalities (five or more premature ventricular contractions, and/or rhythm other than normal sinus rhythm with or without premature atrial contractions), age \(>70\) years, significant aortic valvular stenosis, and poor general medical condition. The contribution of each variable to the CRI was determined by its relative weight, using the scale of Goldman as modified by Epstein et al. \(^{27}\) The maximum score was 4. The evaluated PRI variables included the presence of obesity, current or recent cigarette smoking, recent productive cough, presence of diffuse wheezing or rhonchi, \(\text{FEV}_1/\text{FVC} < 70\%\) predicted, or a preoperative \(\text{PaCO}_2 > 45\ \text{mm Hg}\). All positive variables of the PRI were assigned a value of 1 point and added. The CPRI was calculated by adding the CRI and PRI. The maximum value was 10.

**Postoperative Evaluation**

Postoperative data were collected daily for 30 days after surgery. Only the following cardiac and pulmonary complications were considered as adverse outcome: myocardial infarction, defined by the presence of chest pain, positive ECG changes, and elevated myocardial isoenzyme values; unstable angina, defined by the presence of chest pain and ECG alterations without increased myocardial isoenzyme values; CHF, defined as presence of signs of left heart failure on physical examination with an abnormal chest radiograph for pulmonary edema, and a pulmonary capillary wedge pressure \(>18\ \text{mm Hg}\) or a clinical response to diuretic therapy; arrhythmia, persistent and requiring treatment; reintubation after surgery; mechanical ventilatory support for \(>3\) h after surgery; pneumonia, with temperature \(>38.5^\circ\text{C}\) without any other possible extrapulmonary explanation, purulent sputum, infiltrate on chest radiograph, and treated with antibiotics; lobar atelectasis, evidenced on chest radiograph and requiring bronchoscopy; hypercapnia, when \(\text{PaCO}_2 > 50\ \text{mm Hg}\) or at least \(10\ \text{mm Hg}\) higher than the preoperative value; and pulmonary embolism, diagnosed by pulmonary perfusion scan or pulmonary angiography.

**Statistical Analysis**

Wilcoxon rank test was used to evaluate preoperative parameters. The predictive power of the CPRI, CRI, and PRI was evaluated using the Goodman and Kruskal’s \(\lambda\) and the asymmetric Somers’ \(d\) coefficients with outcome as dependent variable. Catabulation was performed for the entire population and for cohorts. Sensitivity, specificity, positive predictive accuracy (PPA), and negative predictive accuracy (NPA) were calculated for multiple CPRI values and incorporated into receiver operating characteristic curves (ROCCs). The area under the ROCC (ROCC area) was calculated using statistical software (MedCalc for Windows 4.0 software package; Ghent, Belgium). When necessary, data were expressed as mean \(\pm\) SD. \(p\) values \(<0.05\) were considered significant.

**Results**

Ninety-two male and 88 female patients between the ages of 15 and 87 years were studied. Patients underwent 114 lobectomies, 35 wedge resections, 19 pneumonectomies, 5 pleurectomies, 5 lymph node dissections, 1 paravertebral tumor resection, and 1

<table>
<thead>
<tr>
<th>Table 1—Distribution of the Complications Among Patient Population</th>
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<tbody>
<tr>
<td><strong>Complication</strong></td>
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</tr>
<tr>
<td>Cardiac</td>
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<tr>
<td>Arrhythmia</td>
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<tr>
<td>Acute myocardial infarction</td>
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<tr>
<td>CHF</td>
</tr>
<tr>
<td>Pulmonary</td>
</tr>
<tr>
<td>Pneumonia</td>
</tr>
<tr>
<td>Atelectasis</td>
</tr>
<tr>
<td>Reintubation</td>
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<tr>
<td>Elevated (\text{PaCO}_2) &amp; 1 (0.5)</td>
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<tr>
<td>Pulmonary embolism</td>
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<tr>
<td>Deaths</td>
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</tbody>
</table>
thoracic wall resection. Forty-eight (27%) patients developed a total of 80 postoperative complications (Table 1). Twenty-five patients (14%) developed one or more pulmonary complications, 8 patients (4%) developed one or more cardiac complications, and 15 patients (8%) developed both cardiac and pulmonary complications. There were four deaths (2%); two patients died of pulmonary complications and two others died of combined cardiac and pulmonary complications. There was a higher incidence of complications in the pneumonectomy group (9/48 vs 10/132, p<0.5).

Preoperative historical and laboratory data for patients with and without complications are shown in Table 2. The FEV$_1$ was marginally smaller in patients with complications. The FEV$_1$ ranged between 0.75 L and 4.83 L with two of three patients with preoperative FEV$_1$ <1.00 L experiencing complications. The preoperative FVC ranged between 1.33 L and 5.80 L; the only patient with an FVC <1.50 L developed complications.

CPRI ranged from 1 to 7, CRI ranged from 1 to 4, and PRI ranged from 0 to 5. The CPRI, CRI, and PRI had no predictive power for complications in the population studied. The Goodman and Kruskal's $\lambda$ and the asymmetric Somers' $d$ coefficients for CPRI, CRI, and PRI, and their components with outcome as the dependent variable were near zero for all indexes. ROCC areas for CPRI, CRI, and PRI for all complications, cardiac complications, and pulmonary complications are reported in Table 3. There was no statistical difference in the incidence of complications, including deaths in patients with a CPRI ≥4 (12/38, 31%) and patients with a CPRI <4 (36/142, 25%; Fig 1). The four deaths occurred in patients with CPRI values of 2, 2, 3, and 4, CRI values of 1, 1, 1, and 3, and PRI values of 1, 1, 2, and 1. Cohorts of patients stratified by the occurrence of complications for each CPRI parameter are shown in Figures 2 and 3. Only the incidence of myocardial infarction, abnormal ECGs, and preoperative CO$_2$ were statistically different between patients with and without complications.

Separating the patients by surgical procedure, the CPRI had a marginal predictive value for complications in the group of patients who underwent pneumonectomy (n=19; Fig 4). The Goodman and Kruskal's $\lambda$ and the asymmetric Somers' $d$ coefficients for pneumonectomy patients were 0.44 and 0.34, respectively. The sensitivity, specificity, PPA, and NPA for CPRI ≥4, and the ROCC area by patient group are shown in Table 4.

Patients without complications stayed in the hospital 9.64±14.64 days while those who developed complications stayed 17.14±19.39 days. We found no relationship between CPRI, CRI, PRI, and the total length of stay in patients with complications.

### Discussion

This large prospective trial has failed to confirm the validity of the CPRI as a predictor of postoperative complications after pulmonary resection. Secondary statistical analysis demonstrated that the CRI and its components and the PRI and its components had no predictive power for postoperative complications.

Because of the high mortality and morbidity associated with pulmonary resection, clinicians have focused their attention on the adequacy of preoperative evaluation of patients undergoing thoracic surgery. Investigators have used preoperative pulmonary function tests, alone and in combination, radionuclide scans, and exercise oxygen consumption to predict those patients who were most likely to experience complications. The use of preoperative medical history and physical examination data to assess the patients' postoperative risk is an attractive alternative, because it is simple and utilizes information that for the most part is already available. Epstein et al$^{27}$ created the PRI based on preoperative history, physical examination, and simple spirometric findings and combined it with modified Goldman criteria to create the CPRI. They studied 42 patients with 14 experiencing 27 pulmonary and cardiac complications. The investigators showed a

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**Table 2—Preoperative Values and Incidence of Risk Factors in Patients With and Without Complications**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Complications</th>
<th>No Complications</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of patients</td>
<td>48</td>
<td>132</td>
<td></td>
</tr>
<tr>
<td>Age, yr</td>
<td>63.3±1.5</td>
<td>60.2±1.1</td>
<td>0.18</td>
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<tr>
<td>Weight, kg</td>
<td>72.1±2.2</td>
<td>75.4±1.7</td>
<td>0.61</td>
</tr>
<tr>
<td>Pulmonary disease (%)</td>
<td>37/48 (77)</td>
<td>80/132 (60)</td>
<td>0.60</td>
</tr>
<tr>
<td>Cardiac disease (%)</td>
<td>12/48 (25)</td>
<td>15/132 (11)</td>
<td>0.02</td>
</tr>
<tr>
<td>Abnormal ECG (%)</td>
<td>10/48 (21)</td>
<td>12/132 (9)</td>
<td>0.04</td>
</tr>
<tr>
<td>FVC, L</td>
<td>5.0±0.1</td>
<td>3.1±0.1</td>
<td>0.20</td>
</tr>
<tr>
<td>FEV$_1$, L</td>
<td>2.0±0.1</td>
<td>2.2±0.1</td>
<td>0.05</td>
</tr>
<tr>
<td>FEV$_1$/FVC</td>
<td>67.7±2.2</td>
<td>70.9±0.9</td>
<td>0.50</td>
</tr>
<tr>
<td>PaCO$_2$, mmHg</td>
<td>39.1±0.5</td>
<td>41.1±0.4</td>
<td>0.02</td>
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**Table 3—ROCC Areas for Each Index by Type of Complication**

<table>
<thead>
<tr>
<th>Complication Type</th>
<th>CPRI</th>
<th>CRI</th>
<th>PRI</th>
</tr>
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<tbody>
<tr>
<td>All</td>
<td>0.53</td>
<td>0.58</td>
<td>0.51</td>
</tr>
<tr>
<td>Cardiac</td>
<td>0.51</td>
<td>0.51</td>
<td>0.55</td>
</tr>
<tr>
<td>Pulmonary</td>
<td>0.52</td>
<td>0.55</td>
<td>0.51</td>
</tr>
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</table>
strong relation between a CPRI >4 and postoperative cardiac and pulmonary complications. More recently, these same investigators expanded their observations by combining data from these same 42 subjects to data from 32 additional patients to create a possible risk stratification scheme based on the combination of CPRI value and the ability to exercise.29 Despite a similar number of patients with a CPRI score <4 in both groups, 27 of 42 (64%) and 19 of 32 (59%), the incidence of complications in the supplemental group was 50% or 16 of 32, much higher than their earlier reported incidence of 33%, which would suggest a more “sickly” population or a more complex operation. Notwithstanding the lack of information concerning the complexity of surgery in the initial 42 patients, if the CPRI was an impor-
tant predictor of outcome, one would have expected higher overall CPRI scores in the group of patients having more complications.

We preoperatively ascertained CPRI scores in 180 consecutive patients to enable the comparison of predicted and actual outcome. Our population, appearing somewhat healthier to the one studied by Epstein et al.27 with a lower overall CPRI distribution, had 44 patients with a CPRI ≥4. Our complication rate of 27% was only slightly lower than the early report of 33% by Epstein et al.27 As evidenced by ROCC areas close to 0.5, the CPRI did not stratify the sample population by incidence of complications; there was no relation between CPRI and type of complications. In fact, the complication rate was similar for all CPRI values. It is possible that the lack of sensitivity of the CPRI in the sample group was the result of testing a “healthier” population. The CPRI may provide better prediction of outcome in a “sicker” population.

The evaluation of the predictive power of the CPRI in patients undergoing pneumonectomy, a population of patients routinely considered at higher risk for complications, provides some insight into the question of CPRI reliability. The incidence of complications in this group was higher than in the general sample, a finding consistent with other investigators.4,5,17,30 There were 9 complications with 2 deaths in 19 patients who underwent pneumonectomies. A CPRI ≥4 had a modest degree of accuracy predicting complications in postpneumonectomy patients; the index correctly identified four of four complications; however, this parameter failed to identify the other five patients experiencing complications and having a CPRI <4. In patients undergoing pneumonectomy, a CPRI ≥4 had a specificity and PPA of 100% with a sensitivity of 44% and a NPA of 66%. In any analysis, a test with a high sensitivity and high NPA consistently identifies individuals who are disease free and therefore it is useful to screen large populations for a specific disease. However, a test with a high specificity and high PPA will identify patients in a population at very high risk of developing the complication. In this context, the CPRI is a marginally useful test to screen patients scheduled for pneumonectomy; it improved prediction by 34%. Not only does our study suggest that the type of pulmonary surgery performed should be used as a component of any predictive index, but it also

Figure 3. Incidence of complications vs single PRI components as percentage of patient population in each group. Asterisk: significance at p value <0.05.

Figure 4. Number of complications by CPRI values in postpneumonectomies.
suggests that the CPRI may be more helpful in identifying patients most at danger of complication in an overall sicker population.

In an attempt to improve the predictive value of the index, we separately analyzed CRI, PRI, and all of their components. The CRI did not provide any better prediction of complications than the CPRI, and only the presence of a myocardial infarction within 6 months of operation and an abnormal preoperative ECG marginally correlated with the incidence of complications. Also, the PRI and its individual components were not good predictors of postoperative complications in the general population. Only FEV₁ appeared to have minor predictive importance, with two of three patients with FEV₁ <1.00 L experiencing complications. Although some studies have shown FEV₁/FVC to correlate better with outcome than FEV₁, our data support a marginally better predictive value for FEV₁. This result would be in accordance with other investigators who have demonstrated the lack of predictability of spirometric parameters. There was no correlation between indexes and the postoperative length of stay in the hospital.

Surgical resection remains the most effective therapy for non-small cell lung cancer; accordingly, the preoperative evaluation of the patient is important to minimize the risk of postoperative complications. Many preoperative conditions considered as risk factors can be improved by preoperative preparation and postoperative monitoring and treatment. Early identification, especially in the high-risk category, is extremely important. The CPRI does not appear to provide sufficient information. It is undoubtedly possible that there may be interinstitutional differences that do not permit the transfer of the index to other centers, since, as Bolliger et al.30 observed that cigarette smoking, productive cough, and diffuse wheezing or rhonchi are criteria dependent on observer bias.31 This study, however, suggests that a different approach is needed to develop a reliable predictive preoperative tool that can be applied to diverse populations in different institutions.

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