e-ISSN: 0975-1556, p-ISSN:2820-2643

Available online on www.ijpcr.com

International Journal of Pharmaceutical and Clinical Research 2023; 15(9); 376-382

Original Research Article

Prediction of Postoperative Pulmonary Complications on the Basis of Preoperative Risk Factors in Patients who had Undergone Coronary Artery Bypass Graft Surgery

Tauseef Neem Rashid Akhtar[1], Yatin Wagh[2], Pankaj Bhat[3]

[1]Assistant Professor, Respiratory Medicine, JMF's, A.C.P.M. Medical College & Hospital, Sakri Road, Dhule, M.S.

[2]Assistant Professor, General Surgery, JMF's, A.C.P.M. Medical College & Hospital, Sakri Road, Dhule, M.S.

[3]Assistant Professor, Otorhinolaryngology, JMF's, A.C.P.M. Medical College & Hospital, Sakri Road, Dhule, M.S.

Received: 30-5-2023 / Revised: 30-06-2023 / Accepted: 30-07-2023
Corresponding author: Pankaj Bhat
Conflict of interest: Nil

Abstract:

Background and Purpose: Pulmonary complications are among the most frequently reported complications after coronary artery bypass graft (CABG) surgery. However, the risks of postoperative pulmonary complications (PPCs) are not equal for all patients. The aim of this study was to develop a model, based on preoperative factors, for classifying patients with high and low risks for PPCs in order to implement tailored interventions.

Subjects and Methods: Postoperative pulmonary complications were examined in 117 adult patients who had undergone elective CABG surgery at (Location). The presence of preoperative risk factors (N=12) that have been described in the literature was noted for each patient. A risk model was developed by use of logistic regression analysis.

Results: Preoperative risk factors for developing PPCs were an age of ≥70 years, productive cough, diabetes mellitus, and a history of cigarette smoking. Protective factors against the development of PPCs were a predicted inspiratory vital capacity of ≥75% and a predicted maximal expiratory pressure of ≥75%. These risk and protective factors were included in the model (sensitivity=87% and specificity=56%), and a sum score for its clinical use was generated.

Discussion and Conclusion: Six factors that can be determined easily before surgery, with the need for only simple pulmonary testing, can provide a model for identifying patients at risk of developing PPCs after CABG surgery.

Keywords: Coronary artery bypass graft surgery, Postoperative pulmonary complications, Preoperative risk factors, Risk model.

Introduction

Post-Operative Pulmonary Complications (PPC) are most observed complications in preoperative, intraoperative, and postoperative care, PPCs continue to contribute to patient morbidity and mortality, length of stay, and overall use of resources. [1,2] Because of the increasing number and complexity of surgical procedures, as well as the increasing severity of illness and age of patients undergoing surgery, PPCs continue to be a major source of morbidity and mortality.

Interventions such as breathing and coughing exercises, early ambulating, and pulmonary clearing techniques often are used by physical therapists to prevent pulmonary complications after coronary artery bypass graft (CABG) surgery. [3] However, there is controversy concerning both the efficacy of these postoperative procedures in diminishing the incidence of PPCs and the proper strategy for the identification of patients who might benefit from such interventions. [4 –11]

In contrast to the controversy that exists relative to patients undergoing general surgery, similar procedures performed before CABG surgery were shown to be effective and to lower the risk of PPCs. [12–14] Furthermore, in patients who had upper abdominal surgery, preoperative physical therapy was more effective in reducing PPCs in patients who were at moderate or high risk for developing complications after surgery than in patients who were at low risk for developing such complications. [15,16]

Preoperative identification of patients at high risk for developing complications after surgery can help physical therapists to direct their interventions toward people who might benefit from these interventions and may reduce the incidence of PPCs in patients undergoing CABG surgery. Preoperative risk scores are useful for risk assessment, cost-benefit analysis, and studies of interventions. [17] Most scoring systems are designed primarily to predict mortality after adult heart surgery, [18–24] but morbidity has been acknowledged as the major determinant of hospital costs and as a determinant of quality of life after heart surgery. [25,26] Consequently, we believe that there is a need for a risk model that can be used to evaluate preoperative risk factors and to predict morbidity in patients undergoing CABG surgery. By use of such a model, clinicians can identify preoperatively patients who are at risk for developing PPCs. The most frequently used risk factors are advanced age, excess weight (body mass index [BMI]), and a history of cigarette smoking, diabetes mellitus, abnormal pulmonary function, and chronic obstructive pulmonary disease (COPD) 0.2, [27–30] Emergency surgery is also a risk factor for those under- going CABG surgery. [2]

The aim of our study was to develop a risk model, based on preoperative factors, in order to classify patients undergoing CABG surgery into those with a high risk and those with a low risk for developing PPCs. The model should be simple and easy to use in a clinical setting—for instance, by physical therapists—and, in the long run, be appropriate for cost-effectiveness studies.

Method

Patients

Data were collected for patients who underwent elective CABG surgery between December 2019 and February 2022 at the Location. All participating patients provided written informed consent.

Inclusion criteria were elective CABG procedure, age of greater than 18 years, and an ability of the patients to understand informed consent. Exclusion criteria were a history of a cerebrovascular accident; use of immunosuppressive treatments during the 30-day period before surgery; the presence of neuromuscular disorders; or a history of pulmonary surgery, cardiovascular instability, or aneurysms.

On the basis of the definitions of risk factors of the Society of Thoracic Surgeons31 and a review by Brooks- Brunn,2 the following preoperative risk factors were assessed: patient age, sex, BMI, pulmonary functions (ie, inspiratory vital capacity [IVC], forced expiratory volume [FEV1], maximal expiratory pressure [MEP], and maximal inspiratory pressure [MIP]), diabetes mellitus, productive cough, COPD, history of cigarette smoking, Opinion of ENT consultant, and score on the Specific Activity Scale (SAS). Enrolled patients were monitored during admission and after surgery until they were discharged from the hospital.

Data Collection

Before surgery, information regarding demographics and possible preoperative risk factors was obtained by means of a standardized interview by the same physical therapist. The SAS was used to evaluate the functional status of the patients before surgery. To evaluate pulmonary pump function, all participants underwent pulmonary function tests (IVC and FEV1) and respiratory muscle force tests (MIP and MEP), which were administered by the same physical therapist on the day before surgery.

A hospital technician (a microbiologist) who was blinded for preoperative risk factors, pulmonary function test results, and respiratory force test results scored nosocomial infections according to the definitions of the Centers for Disease Control and Prevention (CDC). [32] The technician classified the PPCs by means of the operational definitions given in standard protocols.

Pulmonary Function Tests

Lung volumes (IVC and FEV1) were measured by spirometry. Spirometry was standardized according to American Thoracic Society recommendations and was performed with the patient in a sitting position.33 The value recorded was the best (the highest IVC, FEV1, and forced vital capacity [FVC] measurement) of 3 consecutive attempts. Predicted values for pulmonary functions were calculated from regression equations according to age, height, and sex. [34] The accuracy of the spirometer for volume is claimed to be 2%, or 0.05 L , and the validation limit for flow is claimed to be 3%, or 0.07 L, according to the operating manual for the instrument. The reproducibility criterion used was that the highest FEV1 measurement and the second highest FEV1 measurement should not vary by more than 5%, or 0.10 L. If the first 3 measurements did not agree within 5% of each other, 3 additional measurements were obtained. In another study, [35] we examined the reliability of the measurements that we used (intraclass correlation coefficients=0.98-0.99).

Respiratory Muscle Force Tests

To evaluate maximal respiratory muscle force, the MIP and the MEP were measured with a hand-held pressure gauge. The MIP is thought to reflect the force of the diaphragm, whereas the MEP is believed to reflect the force of abdominal and intercostal muscles. [36] Maximal respiratory muscle force tests (MIP and MEP) are useful when respiratory muscle weakness is suspected as a cause of low lung volumes, or hypoventilation.37 Standardization of the respiratory muscle force tests was carried out as described by Clanton and Diaz.38 Normal values for the MIP and the MEP were calculated from regression equations according to age and sex. [36,39]

Five measurements were recorded, with the criterion that the 2 highest values should not vary by more than 10%. Previous investigators [40] suggested that there could be some overshoot in the recording obtained with some maximal respiratory muscle force meters; therefore, we also calculated the mean of the 5 highest values. We then compared this mean with the single highest maximal respiratory pressure value. When the difference was 5 cm of H_2O or less for 93% of the participants, we believed that overshoot was minimal with our instrument and that most of the participants could sustain their maximal pressure for at least 1 second. Therefore, we report the highest value obtained in 1 second.

Functional Status

To assess preoperative cardiac functional classes, we used self-reported data on the performance of well- defined daily activities (eg, walking, climbing stairs, bicycling, showering, dressing) scored with the SAS.41 This index was developed as an alternative to the New York Heart Association functional classification. Subjects were asked about their ability to undertake activities of known metabolic cost and were placed in 1 of 4 functional classes on the basis of their responses (class I: subject could perform any activity requiring ≥7 metabolic equivalents (METs, where 1 MET=3.5 mL O_2•kg—1•min—1); class II: subject can perform to completion any activity requiring ≥ 5 METs but cannot or does not perform to completion activities requiring ≥7 METs; class III: subject can perform to completion any activity requiring ≥2 METs but cannot or does not perform to completion any activities requiring ≥5 METs; class IV: subject could not perform to completion any activity requiring ≥2 METs). The SAS has been shown to have better interobserver reliability than the New York Heart Association classification (weighted kappa value = 0.62 for all 4 classifications), and results obtained with the SAS have been shown to relate more closely to the results of conventional exercise testing.42 The SAS has a reproducibility of 73% in 75 patients with cardiovascular diseases and correlates well (r =.66) with the duration of treadmill exercise (in seconds). [42,43]

Postoperative Pulmonary Complications

Postoperative pulmonary complications have been defined as "any pulmonary abnormality occurring in the post-operative period that produces identifiable disease or dysfunction that is clinically significant and that adversely affects clinical course." 44 In our study, PPCs were defined according to clinical (symptoms and physical examination), radiologic, and CDC criteria for bronchitis, atelectasis, and pneumonia [45,46] When abnormal radiologic findings occurred and there were no clinical symptoms or changes in auscultation, the complications were considered subclinical.

Data Analysis

The data were analysed with the Software Package for the Social Sciences (SPSS, version 9.0). 47 Data from all subjects were analysed for outliers. The Kolmogorov- Smirnov goodness-of-fit test was used to check for the normality of data distribution. Summary descriptive statistics, including frequencies, means, and standard deviations, were computed for the preoperative variables. Twelve preoperative risk factors (Tab. 2) were dichotomized (0=absent, normal; 1=present, abnormal), and cutoff points for continuous variables (eg, age, BMI, FEV1, IVC, MIP, MEP) were chosen on the basis of the literature and were examined to determine the best association with PPCs. [2, 27–31,48 –50] The potential association of each of the 12 preoperative risk factors with PPCs was evaluated with the Fisher exact test. Relative risks were calculated to measure the degree of association. Separate multiple logistic regression models were developed to determine the effects of the preoperative factors that have a significant association with PPCs by use of the backward procedure. The goodness-of-fit test was used to choose the best predicted model for PPCs.[51]

The validity of data obtained with logistic regression analyses can be studied by predicting the outcome and by comparing this prediction with the known outcome. This process requires the collection of new data. Thus, using the SPSS program, we selected a random sub-sample of 17 subjects (14.5%) from the study sample (N=117) and developed a model based on the remaining subjects (n=100).

We then predicted the outcome for these 17 subjects and compared this outcome with their actual outcome to obtain an indication of the validity of the method. Again, we selected a new sub-sample (a different subsample of 17 subjects), predicted the outcome for these 17 subjects, and compared this outcome with their actual outcome. This simulation was repeated 100 times to determine the sensitivity and specificity of the model.

Development of a Clinical Severity Score and External Validation Procedure

The risk factors in the logistic models were weighted according to their regression coefficients and odds ratios, which enabled the calculation of a total score in order to predict PPCs. Positive and negative predictive values for the total scores were calculated by assuming that the future rate of PPCs would be the same as that observed in the current study. A receiver operating characteristic (ROC) curve was used to measure and compare the accuracies of the models without the use of a specific cutoff point. An ROC curve is a graphic approach to plotting sensitivity versus 1 — specificity for each possible cutoff and to joining the points. If the "cost" of a false-negative result is the same as that of a false-positive result, the best cutoff is one that maximizes the sum of the sensitivity and specificity, which is the point nearest the top left-hand corner. [52]

Results

A total of 139 consecutive patients underwent elective CABG surgery between December 2019 and February 2020. Twenty-two patients were excluded: 6 patients because of cardiovascular instability, 4 patients because they did not 9 patients because they underwent emergency surgery and 3 patients because they died after the operation as a result of a cardiac event. The remaining 117 patients were available for the study.

The technician collected data concerning the existence of bronchitis or pneumonia according to CDC criteria and gathered additional data from the medical records, such as results of auscultation, chest radiographs, samples obtained for bacteriologic analysis, temperature curves, productive cough, hypoxemia, hypercapnia, reintubation, and ventilatory failure. [53] The technician scored pulmonary complications on a scale of 1 to 4.

These 6 significant preoperative risk factors were assigned weights based on the regression coefficients and odds ratios estimated in the logistic model. The risk factors age of ≥70 years and productive cough were given a score of 3 points. The risk factors smoking and diabetes mellitus were given a score of 2 points. The 2 protective factors, predicted IVC of ≥75% and predicted MEP of ≥75%, were given a score of —2 points. With this system, the theoretical maximum total severity score was 10 points and the minimum severity score was —4 points. Each subject's clinical score was determined by use of the weighted risk factors. The sensitivity and the specificity using the operational definitions of Kroenke et al.[45] Because grade 1 pulmonary complications were few and minor, we included them in the "no PPC" group for the remainder of the analysis. In our study, we defined the "PPC group" as all participants having 2 or more grade 2 complications or 1 grade 3 or 4 complications. With this criterion for PPCs, a total of 39 subjects (33%) developed a PPC (grade of ≥2).

Of the 12 preoperative risk factors, 6 had an association with PPCs. These 6 factors (age of ≥70 years, cough with sputum production, smoking within the last 8 weeks, diabetes mellitus, predicted IVC of ≥75%, and predicted MEP of ≥75%) were entered into the multivariate backward logistic regression analysis. Four of these factors (age, cough, smoking, and diabetes mellitus) were associated with a high risk of developing PPCs, and 2 factors (predicted IVC of ≥75% and predicted MEP of ≥75%) were protective against such complications.

As a screening test for the identification of patients with a high risk for PPCs, the cut-off value of ≥—1 was preferred because the sensitivity was higher without much loss in specificity. With this cutoff value, the model identified approximately 9 of the 10 subjects at high risk for PPCs. Because 64 of the 117 subjects scored —1 or more points, the use of the model identified more than 50% of our subjects who were most in need of preoperative and postoperative interventions. To assist people who are at greatest risk for developing complications, we can direct our interventions more aggressively to these people if we can identify them. Subjects identified as being at high risk for developing PPCs had a 44% rate of false-positive results and a 13% rate of false-negative results.

Discussion

Because of the relatively small sample size (N=117), preselection of the 12 potential risk factors was used. Six factors (age of ≥70 years, cough with sputum production, smoking within the last 8 weeks, diabetes mellitus, predicted IVC of ≥75%, and predicted MEP of ≥75%) had an association with the development of PPCs. With the help of logistic regression analysis, a preoperative 6-factor model was identified. In retrospective and prospective studies of patients undergoing CABG surgery, advanced age, excess weight (BMI), smoking, diabetes mellitus, abnormal results of pulmonary function tests, COPD, and emergency surgery consistently have been identified as risk factors for PPCs. [29,30,48,54,56] In our study, 4 of the 6 identified factors were consistent with those reported in the literature (age, smoking, diabetes mellitus, and abnormal pulmonary function tests). However, not all risk factors found in the literature were examined in our study. Emergency surgery was an exclusion criterion in our study. A history of COPD was not identified as an independent risk factor in the multivariate analysis. Our study sample included 20 patients with a history of COPD, of whom 8 (40%) developed a PPC. Potential explanations for this finding include the relatively small number of patients with a history of COPD and the method used to identify this risk factor (patient self-report). The inclusion of BMI slightly weakened the model (sensitivity=79% and specificity=57%). To our knowledge, the risk factor MEP identified in our study has not been reported elsewhere in this context.

Other classification indexes for patients at high risk for PPCs have been developed for use in the clinical setting. The cardiopulmonary risk index (CPRI) was tested previously in patients who have undergone thoracic surgery, with variable results. [57] The CPRI is an algorithm that combines modified Goldman criteria for predicting cardiac complications and a pulmonary index that includes information from the patient's history, spirometry results, and arterial blood gas results. Trayner et al58 evaluated the CPRI in 43 patients undergoing chest and upper abdominal surgery; they demonstrated that a CPRI of >3 had a positive predictive value for the development of PPCs of 100%. Recently, however, Arslan et al [59] found that the CPRI did not predict complications in a group of patients who had undergone thoracic surgery. The limitations of the CPRI are that this algorithm has not been validated for patients undergoing CABG surgery and that the CPRI uses arterial blood gas analyses, which are not routinely ordered preoperatively. Furthermore, the definition of PPCs in the CPRI does not identify transient or self-limiting problems. We tried to eliminate a number of the above-mentioned limitations. First, the 6-factor model is easy to use, and the 6 factors can be scored preoperatively. Second, we used explicit operational criteria to define PPCs. Because complication rates can vary widely depending on the definitions used, explicit definitions will aid future efforts to confirm our findings.

In the literature, the overall incidence of PPCs following CABG surgery varies from 5% to 90%.1 In our study, the incidence of PPCs was 33%, determined on the basis of the explicit 4-grade operational criteria for PPCs. This definition of PPCs has been used in only 1 other study, in which 10 patients with severe COPD (predicted FEV1 of <50%) underwent CABG surgery.45 In that study, 5 of the 10 patients died, and 3 of the 5 deaths were attributable to cardiac rather than pulmonary reasons. In the remaining 2 patients, the cause of death was less clear, but respiratory failure was at least contributory. One of the remaining 5 surviving patients developed a grade 2 pulmonary complication (20%). In our study, only 3 patients had a predicted FEV1 of <50% and these 3 patients all developed a grade 3 PPC.

The potential limitations of our study are the lack of control over a physician's documentation on the medical chart of auscultation, blood gas, and radiographic findings. The PPCs in our study were determined by review of a patient's medical records, and it is possible that physicians failed to document a certain number of minor events, such as atelectasis or cough. If this situation occurred, the incidence of grade 1 and 2 complications in our study sample might have been underestimated. It is also possible that the subsample of patients who had undergone CABG surgery was heterogeneous. Operation time, American Society of Anesthesiologists class, current medications for cardiac conditions, history of previous cardiac surgery, history of clinical evidence of congestive heart failure, electrocardiographic changes, and previous myocardial infarction were not included in our risk classification. However, there is evidence that factors such as longer mean operation time, higher American Society of Anesthesiologists class, and higher Goldman index (cardiac morbidity) are associated with a higher incidence of PPCs. [45]

Conclusion

We studied a simple, bedside risk assessment form to predict the preoperative risks of PPCs in patients who had undergone CABG surgery. We believe that, by using the assessment, clinicians can provide more tailored preoperative and postoperative physical therapy to patients who are at high risk for developing PPCs. However, we did not study whether such a program would be more beneficial than those currently in use. This topic should be the focus of future research. In our retrospective study, we identified 4 independent risk factors and 2 factors that inhibit the development of PPCs following CABG surgery.

The 4 risk factors were age of ≥70 years, productive cough, positive history of diabetes mellitus, and positive cigarette smoking history in the last 8 weeks. The 2 protective factors were a predicted IVC of ≥75% and a predicted MEP of ≥75%. Because complication rates can vary widely depending on the definitions used, explicit definitions can aid future efforts to confirm our findings.

References

1. Brooks-Brunn J. Postoperative atelectasis and pneumonia. Heart Lung. 1995; 24:94 –115.
2. Brooks-Brunn J. Postoperative atelectasis and pneumonia: risk fac- tors. Am J Crit Care. 1995; 4:340 –349.
3. Stiller K, Munday R. Chest physiotherapy for the surgical patient. Br J Surg. 1992; 79:745–749.
4. Jenkins SC, Soutar SA, Loukota JM, Johnson LC, Moxham J. A comparison of breathing

exercises, incentive spirometry and mobilisation after coronary artery surgery. Physiotherapy Theory and Practice. 1990; 6:117–126.
5. Stiller K, Montarello J, Wallace M, et al. Efficacy of breathing and coughing exercises in the prevention of pulmonary complications after coronary artery bypass graft. Chest. 1994; 105:741–747.
6. Sutton P, Pavia D, Bateman J, Clarke S. Chest physiotherapy: a review. Eur J Respir Dis. 1982; 63:188 –201.
7. Jenkins SC, Soutar SA, Loukota JM, et al. Physiotherapy after coro- nary artery surgery: are breathing exercises necessary? Thorax. 1989; 44:634 – 639.
8. Stiller K, Crawford R, McInnes M, et al. The incidence of pulmonary complications in patients not receiving prophylactic chest physiother- apy after cardiac surgery. Physiotherapy Theory and Practice. 1995; 11: 205–208.
9. Johnson D, Kelm C, To T, et al. Postoperative physical therapy after coronary artery bypasses surgery. Am J Respir Crit Care Med. 1995; 152: 953–958.
10. Jenkins S, Akinkugbe, Corry G, Johnson L. Physiotherapy manage- ment following coronary artery surgery. Physiotherapy Theory and Prac- tice. 1994; 10:3– 8.
11. Thornlow D. Is chest physiotherapy necessary after cardiac surgery? Crit Care Nurs. June 1995:39 – 48.
12. Weiner P, Zeidan F, Zamir D, et al. Prophylactic inspiratory muscle training in patients undergoing coronary artery bypass graft. World J Surg. 1998; 22:427– 431.
13. Rajendran A, Pandurangi U, Murali R, et al. Pre-operative short- term pulmonary rehabilitation for patients of chronic obstructive pulmonary disease undergoing coronary artery bypass graft surgery. Indian Heart J. 1998; 50:531–534.
14. Castillo R, Haas A. Chest physical therapy: comparative efficacy of preoperative and postoperative in the elderly. Arch Phys Med Rehabil. 1985; 66:376 –379.
15. Chumillas S, Ponce J, Delgado F, et al. Prevention of postoperative pulmonary complications through respiratory rehabilitation: a con- trolled clinical study. Arch Phys Med Rehabil. 1998; 79:5–9.
16. Olse´n M, Hahn I, Nordgren S, et al. Randomized controlled trial of prophylactic chest physiotherapy in major abdominal surgery. Br J Surg. 1997; 84:1535–1538.
17. Geissler HJ, Ho¨lzl P, Marohl S, et al. Risk stratification in heart surgery: comparison of six score systems. Eur J Cardiothorac Surg. 2000; 17:400 – 406.
18. Tremblay NA, Hardy JF, Perault J, Carrier M. A simple classification of the risk of cardiac surgery: the first decade. Can J Anaesth. 1993; 40: 103–111.
19. Nashef SAM, Roques F, Michel P, et al. European system for cardiac operative risk evaluation (EuroSCORE). Eur J Cardiothorac Surg. 1999; 16:9 –13.
20. Roques F, Nashef SAM, Michel P, et al. Risk factors and outcome in European cardiac surgery: analysis of the EuroSCORE multinational database. Eur J Cardiothorac Surg. 1999; 15:816 – 823.
21. Pons JMV, Granados A, Espinas JA, et al. Assessing open heart surgery mortality in Spain through a predictive risk model. Eur J Cardiothorac Surg. 1997; 11:415– 423.
22. Tu JV, Jaglal SB, Naylor CD. Multicenter validation of a risk index for mortality, intensive care unit stay, and overall hospital length of stay after cardiac surgery. Circulation. 1995; 91:677– 684.
23. Hattler TL, Madia C, Johnson C, et al. Risk stratification using the Society of Thoracic Surgeons program. Ann Thorac Surg. 1994; 52: 1348 –1352.
24. Parsonnet V, Dean D, Bernstein AD. A method of uniform stratifi- cation of risk for evaluating the results of surgery in acquired adult heart disease. Circulation. 1989; 79:3–12.
25. Higgins TL. Quantifying risk and assessing outcome in cardiac surgery. J Cardiothorac Vasc Anesth. 1998; 12:330 –340.
26. Roques F, Gabrielle F, Michel P, et al. Quality of care in adult heart surgery: proposal for a self-assessment approach based on a French multicenter study. Eur J Cardiothorac Surg. 1995; 9:433– 440.
27. Gaynes R, Bizek B, Mowry-Hanley J, Kirsch M. Risk factors for nosocomial pneumonia after coronary artery bypass graft operations. Ann Thorac Surg. 1991; 51:215–218.
28. Carrel T, Schmid E, Segesser L, et al. Risk factors for postoperative pneumonia. Thorac Cardiovasc Surg. 1991; 39:85– 88.
29. Windsor J, Hill G. Risk factors for postoperative pneumonia. Ann Surg. 1988; 208:209 –214.
30. Nogare A. Nosocomial pneumonia in the medical and surgical patient: risk factors and primary management. Med Clin North Am. 1994; 78:1081–1090.
31. Society of Thoracic Surgeons. Definitions of terms of the Society of Thoracic Surgeons national cardiac surgery database. Ann Thorac Surg. 1994; 58:271–273.
32. Dal Nogare A. Nosocomial pneumonia in the medical and surgical patient. Med Clin North Am. 1994; 78:1081–1090.

33. American Thoracic Society. Standardization of spirometry: 1994 update. Am Rev Respir Crit Care Med. 1995; 152:1107–1136.
34. Quanjer PH. Standardisation of lung function testing. Bull Eur Resp. 1983; 19:1–95.
35. Verborg C, Hulzebos H, Van Meeteren N. Reproduce zerbaarheid van long functiemetingen. Fysiopraxis. 2000; 9:15–17.
36. Enright P, Kronmal R, Manolio T. Respiratory muscle strength in the elderly; correlates and reference values. Am J Respir Crit Care Med. 1994; 149:430 – 438.
37. Reid W, Dechman G. Considerations when testing and training the respiratory muscles. Phys Ther. 1995; 75:971–982.
38. Clanton T, Diaz P. Clinical assessment of the respiratory muscles. Phys Ther. 1995; 75:983–995.
39. Black L, Hyatt R. Maximal respiratory pressure: normal values and relationship to age and sex. Am Rev Respir Dis. 1969; 99:696 – 702.
40. Smyth R, Chapman K, Rebuck A. Maximal inspiratory and expira- tory pressure in adolescents. Chest. 1984; 86:568 –572.
41. Lee T, Shammash J, Ribeiri J, et al. Estimation of maximum oxygen uptake from clinical data: performance of the Specific Activity Scale. Am Heart J. 1988; 115:203–204.
42. Goldman L, Hashimoto B, Cook E, Loscalzo A. Comparative reproducibility and validity of systems for assessing cardiovascular functional class: advantages of a new Specific Activity Scale. Circulation. 1981; 64:1227–1234.
43. Guyatt G, Thompson P, Berman L, et al. How should we measure function in patients with chronic heart and lung disease? J Chronic Dis. 1985; 38:517–524.
44. O'Donohue W. Postoperative pulmonary complications: when are preventive and therapeutic measures necessary? Postgrad Med. 1992; 91: 167–175.
45. Kroenke L, Lawrence V, Theroux M, Tuley M. Operative risk in patients with severe obstructive pulmonary disease. Arch Intern Med. 1992; 152:967–971.
46. Garner J, Jarvis W, Emori G, et al. CDC definitions for nosocomial infections. Am J Infect Control. 1988; 16:128 –140.
47. Norusis M. SPSS Professional Statistics 7.5. Chicago, Ill: SPSS Inc; 1997.
48. Harman E, Lillington G. Pulmonary risk factors in surgery. Med Clin North Am. 1979; 63:1289 –1298.
49. Pedersen T, Eliasen K, Henriksen E. A prospective study of risk factors and cardiopulmonary complications associated with anaesthe- sia and surgery: risk indicators of cardiopulmonary morbidity. Acta Anaesthesiol Scand. 1990; 34:144 –155.
50. Edwards F, Clark R, Schwartz M. Coronary artery bypass grafting: the Society of Thoracic Surgeons national database experience. Ann Thorac Surg. 1994; 57:12–19.
51. Hosmer DW, Lemeshow S. Applied Logistic Regression. New York, NY: John Wiley & Sons Inc; 1989.
52. Altman DG. Practical Statistics for Medical Research. London, England: Chapman & Hall; 1991.
53. Afdeling Ziekenhuis Hygie¨ne and Infectiepreventie UMC Utrecht. Registratie van Ziekenhuisinfecties op het Hart-Long-Instituut van het Acade- misch Ziekenhuis Utrecht bij Pati¨enten met een Cardiochirurgische Ingreep. Utrecht, the Netherlands: UMC Utrecht; 1995:1–28.
54. Spivak S, Shinozaki T, Albertini J, Deane R. Preoperative prediction of postoperative respiratory outcome. Chest. 1996; 109:1222–1230.
55. Kurki T, Kataja M. Preoperative prediction of postoperative mor- bidity in coronary artery bypasses grafting. Ann Thorac Surg. 1996; 61: 1740 –1745.
56. Torrington KG, Henderson CJ. Perioperative respiratory therapy (PORT): a program of preoperative risk assessment and individualized postoperative care. Chest. 1988; 93:946 –951.
57. Epstein S, Faling L, Daly B. Predicting complications after pulmo- nary resection: preoperative exercise testing vs a multifactorial cardio- pulmonary risk index. Chest. 1993; 104:694 –700.
58. Trayner E, Girisch M, Gottlieb S. Symptom limited stair climbing and the cardiopulmonary risk index as predictors of postoperative pulmonary complications after high risk surgery: a multicenter trial. Am J Respir Crit Care Med. 1995; 151:A292.
59. Arslan V, Barrera R, Ginsberg R. Cardiopulmonary risk index (CPRI) does not predict complications after thoracic surgery. Am J Respir Crit Care Med. 1996; 153:A676.