The Influence of Nutritional Status on Complications After Operations for Lung Cancer

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Background. Nutritional status is known to play an important role in determining outcome after many types of operations but its importance relative to nonnutritional indices in patients undergoing an operation for lung cancer is unclear.

Methods. Detailed nutritional and nonnutritional assessment of 52 patients undergoing surgical resection of lung cancer was performed. The frequency of postoperative complications and length of intercostal drainage time were recorded, and the relation between preoperative indices and postoperative outcome was assessed.

Results. Patients who died or needed reventilation had poorer nutritional status, worse lung function, and lower maximum expiratory pressures than those who did not. Using multiple logistic regression, the best model (R^2 = 0.39) to predict death combined operation type, preoperative carbon monoxide transfer factor (% predicted), and maximum expiratory pressure (% predicted). Operation type and the fat-free mass index (FFMI) alone were only slightly less informative (R^2 = 0.35). For reventilation the best model (R^2 = 0.80) combined operation type, body mass index (BMI), and maximum expiratory pressure (% predicted). Intercostal drainage time after lobectomy was significantly related only to preoperative lymphocyte count (p = 0.004) and subjective global assessment score (p = 0.02).

Conclusions. Impaired nutrition is an important predictor of death and the need for reventilation after an operation for lung cancer, and the selection of patients for lung resection might be improved by measuring simple nutritional indices such as BMI and the FFMI.

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Studies of patients undergoing various types of operations have shown that nutritional depletion is associated with poor outcome and increased risk of complications, particularly postoperative infections [1]. Surgical treatment of early lung cancer remains the approach most likely to achieve cure, but is only possible in a minority. Some studies suggest that in those patients with operable disease, certain nutritional indices such as serum albumin concentration may predict complications after an operation [2]. We have shown that severe nutritional depletion is uncommon in those referred for thoracotomy for lung cancer [3]. However, it is still unclear whether lesser degrees of nutritional depletion have any influence on postoperative morbidity and mortality. Recognition of specific prognostic factors might lead to interventions or increased postoperative surveillance that would improve outcome. We have therefore prospectively assessed the prognostic value of nutritional and nonnutritional factors in determining outcome after potentially curative surgical procedures for lung cancer.

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Material and Methods

Patients

Patients were recruited after referral to the cardiothoracic surgeons at the Freeman Hospital, Newcastle upon Tyne, between January 1995 and May 1997. All patients gave written informed consent and the local Ethics Committee approved the study. Only patients who had attempted curative resection for lung carcinoma are included in the present study. The decision to undertake surgical resection was made by the surgeon concerned using conventional clinical, radiologic, and spirometric criteria, without reference to the results of the nutritional assessment.

Surgical Procedures

The routine surgical and anesthetic procedure included preoperative rigid bronchoscopy in the anesthetic room to confirm operability, and single lung ventilation using a Robertshaw dual lumen endobronchial tube during the operation. At the end of the procedure two intercostal drainage tubes were placed in the pleural cavity and attached to underwater seals. Patients were woken up and extubated on the operating table and spent their first 12 to 24 hours in a thoracic surgical high-dependency unit before moving to a thoracic surgical ward. All patients were given intravenous flucloxacillin (or clindamycin if allergic) on induction of anesthesia and for at least 48 hours after an operation. A thoracic paravertebral nerve block was performed after induction using a single

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Table 1. Nutritional and Dietary Variables for 52 Patients Undergoing Resection of Lung Cancer

Test	No.	Mean	Range
Body mass index (BMI) kg/m^2	52	25.1	16.8–35.5
% ideal body weight (%IBW)	51	107.0	76.3–144.1
% predicted weight[b]	51	98.2	69.8–142.4
Fat-free mass index (FFMI) kg/m^2	50	17.5	12.6–23.1
Albumin g/L	51	44.8	37.0–51.0
Transferrin g/L	51	2.53	1.70–4.30
Prealbumin g/L	51	0.28	0.13–0.45
Retinol-binding protein mg/L	51	27.4	13.6–50.4
Lymphocyte count $\times 10^9$/l	51	1.98	0.79–4.41
% predicted tricpes skin-fold thickness[b]	50	92.2	30.0–192.0
% predicted subscapular skin-fold thickness[b]	50	106.0	34.0–228.0
% predicted bone-free midarm muscle area[b]	50	101.0	46.0–186.0
Subjective global assessment score (categories A:B)	52	25:27	
Daily energy intake[c] (BMR)	41	136.8	55.7–203.0
Daily protein intake[d] (% adjusted (RNI)	40	154.2	64.4–294.9
Daily Vitamin C intake (mg)	41	45.9[e]	1.6–502.3

[a] From the Metropolitan Life Insurance Company, 1983. [b] % age-corrected median from Frisancho (1984). [c] % predicted basal metabolic rate (BMR), see Jagoe et al [3]. [d] Reference nutrient intake (RNI) using the ideal body weight (IBW) correction, see Jagoe et al [3]. [e] Median.

injection of 20 ml 0.5% bupivicaine and early postoperative analgesia was usually achieved with a patient-controlled morphine infusion. Standard postoperative physiotherapy was performed with emphasis on full reexpansion of the remaining lung tissue by use of breathing exercises and early ambulation. Help with sputum clearance was given as necessary.

Nutritional Measurements and Dietary Records

Nutritional assessments of patients were undertaken as described in the companion paper [3]. The assessments included anthropometric measurements: height, weight, skin-fold thickness, grip strength, and fat-free mass, serum protein concentrations, and absolute lymphocyte count. Patients also completed a 5-day prospective dietary record at home before admission that was analyzed to give average daily intake of energy, protein, and Vitamin C. A summary of the nutritional and dietary measurements is shown in Table 1. Geographic and time constraints meant that not all patients could complete all the nutritional tests before an operation.

Complications and Outcomes Measured

The categories of complications are listed in Table 2. Complications were assessed prospectively by a single observer (RTJ) in the hospital until discharge or death, and up to 30 days after an operation following successful discharge. Death was defined as that occurring up to 30 days postoperatively or before discharge if the patient remained in the hospital at 30 days. Time from the operation to removal of all intercostal drains and time to discharge were noted.

Respiratory Function

Spirometry and single breath carbon monoxide transfer factor (T_LCO) were measured according to American Thoracic Society criteria [4] using the Sensormedics 2200 and 6200 (Sensormedics Corp, Bilthoven, The Netherlands). Maximum inspiratory pressure (MIPs) and maximum expiratory pressure (MEPs) were measured using a portable meter (Precision Medical Ltd, Pickering, UK) with a nose clip and flanged mouthpiece. MIP was measured from residual volume, and MEP from total lung capacity. The maximum pressure averaged more than 1 second from four attempts at each maneuver and was recorded. Results were expressed as actual values and percent predicted [5].

Postoperative lung function was also estimated from the preoperative values and the number of segments resected [6]. The predicted postoperative (ppo) values for percent predicted forced expiratory volume in 1 second (FEV_1) ($ppoFEV_1\%$) and T_LCO ($ppoT_LCO\%$) were calculated as: $ppoFEV_1\% = FEV_1\%(\text{preop}) \times [1 - (\text{total segments resected}/19)]$; $ppoT_LCO\% = T_LCO\%(\text{preop}) \times [1 - (\text{total segments resected}/19)]$.

Performance Status, Surrogate Marker for Cardiovascular Disease and Staging

Performance status was assessed using the World Health Organization scale, and medication being taken preoperatively was recorded. Those patients taking any medication for treatment of diabetes, cardiac or cardiovascular diseases were assigned to the cardiovascular risk group for analysis of complications. The staging reported here is based on information that included the histologic appearances of resected specimens [7].

Statistical Methods

The data were analyzed using the Statview software (Version 5.0, SAS Inc, Cary, NC). Means were compared using Student's t test or the Mann-Whitney U test, and proportions were compared using the χ^2 or Fisher's exact test as appropriate. Time-related outcomes were assessed using Cox's proportional hazard model. Univariate analysis of preoperative variables versus postoperative outcome inevitably involved multiple significance testing. Therefore, for a result to be regarded as significant, agreement between the results of variables of similar type (eg different skin-fold thickness measurements) was required, in addition to a p value less than 0.05. The nonnutritional variables assessed were operation type (pneumonectomy versus lesser resection, hereafter called lobectomy), age, sex, smoking status (current versus ex-smoker or never smoked), lung function, maximum respiratory pressures, pathologic stage (I or II versus III or IV) [7], performance status, and evidence of cardiovascular disease.

Multivariate logistic regression analysis of complications was performed using variables with p less than 0.05

Table 2. Postoperative Complications in 52 Patients

	Type	Definition	Frequency	
			No.	Percent
1	Any complication	Death or one or more complication(s) or both	34/52	65.4
2	Death	Occurring within 30 days of an operation or > 30 days if still in hospital	7/52	13.5
3	Wound breakdown	Wound needing surgical repair, or new serous discharge at home requiring daily dressing	0/49	0
4	Wound sepsis	Inflammation/purulent discharge ± positive swab culture given specific oral/topical antibacterial treatment	4/49	8.2
5	Pneumonia	New shadowing on CXR, purulent sputum, ± positive culture, treated with antibiotics	12/49	24.5
6	Bronchitis	Purulent sputum without new CXR, changes, treated with antibiotics	7/49	14.3
7	Mini-tracheostomy	Placement of mini-tracheostomy to aid removal of secretions	2/49	4.1
8	Atelectasis	Confirmed on CXR needing bronchoscopy or tracheal suction in the absence of signs of pulmonary infection	1/49	2.0
9	Anaemia	Needing transfusion after day of operation	4/49	8.2
10	Broncho-pleural fistula	Confirmed with CXR	1/49	2.0
11	Persistent air leak	Requiring pleurodesis before intercostal drain removed	5/50	10.0
12	Other sepsis	Confirmed with positive culture	3/49	6.1
13	Reventilation	Reintubated and ventilated for respiratory failure	6/49	12.2
14	Miscellaneous complications	Any other unexpected event requiring intervention or treatment	16/49	32.7
15	Septic complications	One or more of 4, 5, 6, or 12 above	22/49	44.9
16	Pulmonary complications	One or more of 5, 6, 10, 11, or 13 above	20/49	40.8

CXR = chest x-ray.

in univariate analysis. A backwards-stepwise method was used with variables retained in the model if their logistic likelihood ratio *p* value was less than 0.05. Non-nutritional variables were entered first with the nutritional variables entered subsequently to see what additional explanatory effect they had. The combination of independent variables giving the best explanation of the outcome (using the R^2 statistic) was adopted.

Results

Patients

Out of 60 patients undergoing thoracotomy [3] 8 patients were excluded from this study because they had did not have operable lung cancer. Of the remaining 52 patients, 6 had disease that proved to be nonresectable at the time of the operation, and 2 patients had benign disease on histologic examination of the operative specimens. Demographics, performance status, lung function, maximum respiratory pressures, operation type, and histologic details of the remaining 52 patients are shown in Table 3, and nutritional and dietary data are summarized in Table 1. Twelve patients had pneumonectomy (8 right, and 4 left) and 6 patients had bilobectomy including 2 patients with additional rib-resection.

On the basis of postoperative staging, 43 out of 52 patients had stage I or II disease, 4 patients had stage IIIa and 2 patients had stage IIIb disease, from which the latter had satellite tumor nodules in the resected lobe. Three patients had stage IV disease (2 patients had bi-lobectomies with metastases in a second lobe and 1 patient had a pneumonectomy with metastatic deposits on the parietal pleura).

Deaths, Complications, and Other Outcomes

Seven patients died (see Table 4) including 2 patients that died more than 30 days postoperatively. The deaths included 4 of the 12 patients who had pneumonectomy (all right pneumonectomy), and 3 of the 40 patients who had lesser procedures. All patients who died had stage I or II disease. One patient (patient 2) died immediately after the operation; no specific cause of death was established at postmortem but an arrhythmia was suspected. Patient 4 had a lobectomy and was discharged after 9 days but was readmitted 5 days later with a broncho-pleural fistula and soiling of the contralateral lung. A completion pneumonectomy was performed but he died in the hospital 61 days after his original operation.

Table 3. Demographics, Respiratory Function and Pathological Findings in 52 Subjects Undergoing Resection of Lung Cancer

Age (yrs)		Mean (SD)	64.4 (9.1)
		Range	36–80
Sex	M:F		35:17
Performance status	0:1:2 (n = 46)		12:30:4
Smoking status	Current[a]: Exsmoker or never smoked		32:20
Lung function	FEV_1 (L)	Mean (SD)	2.1 (0.6)
	FEV_1 % (n = 51)		81.8 (23.4)
	T_LCO (mmoL/kPa/min)		5.9 (1.9)
	T_LCO% predicted (n = 49)		72.6 (19.4)
Maximum mouth pressure	MEP (cm H_2O)	Mean (SD)	105.4 (34.7)
	MEP% predicted		94.4 (29.6)
	MIP (cm H_2O)		68.8 (22.7)
	MIP% predicted		92.6 (30.0)
Operation type	Pneumonectomy		12
	Bi-Lobectomy		6
	Lobectomy		33
	Segmentectomy		1
Histology	Squamous		26
	Adenocarcinoma		13
	Large cell		8
	Adeno-squamous		1
	Mixed large/small cell		2
	Bronchio-alveolar		1
	Carcinosarcoma		1
Stage	I		35
	II		8
	III		6
	IV		3

[a] Current smokers included those who had stopped for less than 12 months, ex-smokers were those who had stopped smoking 12 months or more.

F = female; FEV_1 = forced expiratory volume in 1 second; M = male; MIP = maximum inspiratory pressure; MEP = maximum expiratory pressure; SD = standard deviation; T_LCO = single breath carbon monoxide transfer factor.

The frequency of individual complications and groups of complications is shown in Table 2. Full details of in-hospital course and complications were recorded for all patients. However, for 2 patients, details of progress after discharge until 30 days postoperatively could not be obtained apart from confirming that they were still alive. These 2 patients and the 1 patient that died on the same day of the operation were excluded from analysis of certain complications.

After lobectomy the median intercostal drainage time was 4 days (range, 1 to 17 days). The median hospital stay for the patients being discharged was 7 days (range, 4 to 34 days) with no significant difference between those patients having lobectomy (median, 7 days) or pneumonectomy (median, 7 days).

Univariate Analysis for Death and Complications

Patients who died were more likely to have had lower indices of body weight, skin-fold thickness, respiratory function, and maximum expiratory pressures. These patients were also more likely to have been smokers, and to have undergone pneumonectomy (Table 5). Patients who needed reventilation after the operation were also

Table 4. Details of Patients Who Died

No.	Sex	Age	Operation	Cause of Death	Postoperative Days
1	F	63	P	Pneumonia and respiratory failure	6
2	F	66	L	Cardiac arrest (suspected arrhythmia)	0
3	F	68	P	Pneumonia and respiratory failure	8
4	M	47	L	Pneumonia, bronchopleural fistula, respiratory failure	61
5	M	52	P	Pneumonia	21
6	M	73	P	Pneumonia and respiratory failure	43
7	M	77	L	Cardiac arrest and bowel infarct	5

F = female; L = lobectomy; M = male; P = pneumonectomy.

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Table 5. Univariate Analysis of Factors Related to Death and Reventilation

	Died? No	Died? Yes		Reventilated? No	Reventilated? Yes	
Continuous variables	Mean	Mean	p^a	Mean	Mean	p^a
BMI	25.7	21.5	0.02	25.8	19.6	0.001
%IBW	109.4	92.1	0.02	109.6	84.8	0.001
%Weight change	−1.2	−1.5	0.91	−0.9	−3.7	0.25
FFMI	17.9	15.4	0.03	17.8	15.0	0.02
%BFMAMA	103.9	83.6	0.05	103.9	79.8	0.03
%TSF	97.2	61.4	0.01	96.8	54.5	0.004
%SSSF	112.4	66.7	0.03	111.4	49.8	0.003
Albumin	44.9	44.3	0.63	44.8	44.7	0.91
Grip Z	0.15	0.18	0.95	0.18	−0.15	0.46
Age	64.5	63.7	0.83	65.0	58.2	0.09
FEV_1%	82.7	76.4	0.52	82.2	75.0	0.48
T_LCO%	75.0	57.7	0.03	73.8	57.5	0.05
ppoFEV_1%	63.2	45.6	0.06	62.6	41.4	0.03
ppoT_LCO%	57.2	34.6	0.003	56.0	32.0	0.003
ppoProduct	3763	1682	0.01	3632	1369	0.007
MEP (cm H_2O)	109.7	79.0	0.03	109.6	78.0	0.04
MEP%	98.1	71.5	0.02	98.6	65.2	0.009
Categorical variables	Ratio	Ratio	p^b	Ratio	Ratio	p^b
Sex (M/F)	31/14	4/3	0.67	30/13	4/2	1.0
Perf status (0/1/2)	11/25/4	1/5/0	0.55[c]	11/23/4	0/5/0	0.22[c]
Operation (P/L)	8/37	4/3	0.04	8/35	4/2	0.03
Stage (I-II/III-IV)	36/9	7/0	0.33	34/9	6/0	0.58
Smoking (Y/N)	25/20	7/0	0.04	25/18	6/0	0.07
CVS meds (Y/N)	25/20	4/3	1.0	23/20	3/3	1.0

[a] Unpaired *t* test; [b] Fisher's exact test apart from [c] = χ^2 squared test.

BMI = Body mass index; %BFMAMA = % predicted bone-free midarm muscle area; CVS meds = medication for cardiovascular disease (see Material and Methods); F = female; FFMI = fat-free mass index; Grip Z = grip strength Z score; %IBW = % ideal body weight; L = lesser resection; M = male; MEP = maximum expiratory pressure; MEP% = % predicted MEP; Operation = pneumonectomy (P) versus lesser resection (L); P = pneumonectomy; Perf status = Performance status; ppoProduct = ppoFEV_1% × ppoT_LCO%; %SSSF = % predicted subscapular skinfold thickness; T_LCO% = % predicted single breath carbon monoxide transfer factor; %TSF = % predicted triceps skinfold thickness.

more likely to have had lower indices of body weight, skin-fold thickness, respiratory function, and expiratory pressures, and to have undergone pneumonectomy (Table 5).

There were similar trends of lower nutritional indices (weight and skin-fold thickness) among those developing pneumonia (No. 5, Table 2) or all pulmonary complications (No. 16, Table 2), but these were less consistent than for death and reventilation. Specific preoperative nutritional variables such as serum protein concentrations and grip strength were not related to the outcomes assessed. Smokers had lower nutritional indices than nonsmokers (eg, mean body mass index [BMI] smokers versus nonsmokers: 23.8 versus 27.2, $p = 0.006$) and were more likely to have a septic or pulmonary complication (Nos. 15 and 16, Table 2, $p = 0.02$, and 0.01, respectively), but smoking was not related to occurrence of pneumonia (No. 5, Table 2, $p = 0.17$). Lung function tests and maximum respiratory pressures were not significantly lower in those who developed pneumonia compared to those who did not.

Multivariate Analysis for Death and Reventilation

Nonnutritional factors were assessed first and the best model was obtained with a combination of operation type, T_LCO%, and MEP percent predicted (MEP%) ($R^2 = 0.39$). When each nutritional variable was added to this model in turn, the fat-free mass index had the strongest effect, and only the operation type remained significant when combined with the fat-free mass index (FFMI). However, there was no additional explanatory effect for the model overall: operation type and the FFMI ($R^2 = 0.35$) (Table 6).

The R^2 values obtained were relatively low implying that most of the variability in outcome (death) was not explained by the variables in the models. However, it is noteworthy that the patient who died immediately after the operation (Table 4, patient 2), was one of the most obese (BMI = 33.2). When this patient was excluded from the analysis, the R^2 values were much higher and the effect of nutritional variables on risk of death was much clearer. The best model then included only ppoT_LCO% and % ideal body weight (IBW) ($R^2 = 0.86$).

Table 6. Best Models From Logistic Regression Analysis of Death and Reventilation

		Model Coefficient	Likelihood Ratio Test p Value	R^2
Death				
	Intercept	4.765		
	Operation type	2.792	0.01	
	MEP%	−0.042	0.04	
	T_LCO%	−0.062	0.05	0.39
	Intercept	7.702		
	FFMI	−0.642	0.003	
	Operation type	3.220	0.005	0.35
Reventilation				
	Intercept	50.162		
	BMI	−2.344	0.0005	
	Operation type	7.454	0.001	
	MEP%	−0.085	0.02	0.80

BMI = body mass index; FFMI = fat-free mass index (kg/m^2); MEP% = % predicted maximum expiratory pressure; Operation type = pneumonectomy versus lesser resection; T_LCO = single breath carbon monoxide transfer factor.

When the factors predicting the need for reventilation were assessed in the same way, the best model again included operation type, T_LCO%, and MEP% ($R^2 = 0.57$). When nutritional variables were added, a large improvement in the overall model was observed. The best model included BMI, operation type, and MEP% ($R^2 = 0.80$) (Table 6).

Intercostal Drainage Time

Intercostal drainage after lobectomy was analyzed using Cox's proportional hazards model. Only lymphocyte count (likelihood ratio test, $p = 0.006$), percent of predicted subscapular skin-fold thickness ($p = 0.01$), and subjective global assessment score ($p = 0.02$) were significantly related to drainage time individually. When these factors were combined, the lymphocyte count ($p = 0.004$) and subjective global assessment score ($p = 0.02$) remained significant independent predictors of time to removal of intercostal drains, although the dominant effect was from the lymphocyte count.

Comment

Although our patients with operable lung cancer had less severe nutritional depletion than reported in earlier studies [3], the findings show that nutritional status may, nonetheless, be an important factor in determining early postoperative outcome. For predicting death after an operation, the FFMI was approximately equivalent to the combined effect of preoperative T_LCO% and MEP%. Furthermore BMI was of overriding importance in determining the need for reventilation. Unlike previous studies [2], we found that reported weight loss, serum protein concentrations, and other indices, such as grip strength, did not predict outcome.

Many studies of nutrition in patients who have undergone operations have shown that nutritional status has an important influence on outcome [1]. Although most studies have related to gastrointestinal operations, an independent effect of nutritional status in predicting outcome has also been found in vascular [8], head and neck [9], orthopedic [10], and urologic [11] operations.

Factors Affecting Outcome After Operations for Lung Cancer

The outcome of an operation for lung cancer is clearly related to the extent of the operation and to preoperative lung function. Other factors such as age, male sex, and previous severe cardiac or pulmonary disease are associated with a poorer outcome in some series [12–15].

Several studies have been performed in patients designated high risk for lung resection by conventional criteria, to establish whether some of these patients can be offered surgical treatment with acceptable risk. Many have used lung function calculated by using quantitative pulmonary scintigraphy [16] and the number of bronchopulmonary segments to be resected or both [6]. The ppoT_LCO% was the best predictor of death and respiratory failure in some series [12, 16], whereas others found the ppoFEV_1 (liters) [6] or the ppo product (ppoFEV_1% x ppoTLCO%) [17] better predictors of death. In some studies (including the present) the values were calculated after the operations [6, 12] and the prospective value of such estimates may have been overstated as a result.

The role of nutrition in predicting the outcome of operations for lung cancer has been addressed in only a few studies. Pierce and colleagues [17] found that BMI was the best predictor of respiratory complications in those having lobectomy or lesser resections. Busch and colleagues [2] retrospectively reviewed 103 consecutive patients and found that extended resection, neoadjuvant chemotherapy, weight loss more than 10%, and serum albumin less than 37 g/L were associated with increased risk of complications. In multivariate analysis only extended resections (involving the chest wall) and serum albumin remained significant.

One mechanism by which nutritional status may influence outcome is by the effects on respiratory muscle strength. Nomori and colleagues [18] showed that those with lower maximum respiratory pressures had more pulmonary complications after thoracic surgery. In the present study, maximum expiratory pressure (MEP%) was important in determining death and the need for reventilation. One possible reason for its predictive value might be the importance of expiratory muscle strength in generation of an effective cough.

Comparing results of different studies is complicated by the variation in definitions. Arbitrary designation of complications into major and minor categories, different patient inclusion criteria, selective reporting of complications, and variations in frequency of adjuvant or perioperative treatments may all affect the results [15, 19].

Death Rates

The overall death rate in the present study (7 out of 52) is similar to that of Pierce and colleagues [17]. Although higher than United Kingdom, national in-hospital mortality rates (lobectomy 2.6%, pneumonectomy 6.9%; D Watson, personal communication, 1999), the differences from our data are not statistically significant (Fisher's exact test, $p = 0.62$, 0.32, respectively). Furthermore we chose to include all deaths that occurred within 30 days of operation, as well as in-hospital deaths of patients who remained after 30 days. This is a more inclusive definition than used to generate the national statistics and by some other authors [13]; and some of the differences between different studies are attributable to varying definitions of mortality. Accurate data collection after discharge is difficult and there is a danger that in larger series, data on death rates after hospital discharge may be incomplete. In addition, all those patients who died after pneumonectomy in the present study had right pneumonectomy, which involves resection of the largest amount of lung tissue and in the elderly at least, this has a significantly higher mortality rate than left pneumonectomy [20].

Reventilation

Six patients required ventilation because of respiratory failure during recovery from the operation. The best overall model to predict need for reventilation combined operation type, BMI, and MEP%. Five of the 6 patients who needed reventilation died, usually after a prolonged period of intensive care. Thus the morbidity, mortality, and expense of this complication are substantial, and it is clear that identifying those at risk of needing reventilation is of major importance. The present study suggests that poor nutritional status has a considerable influence in determining the need for reventilation.

As mentioned previously, many nonnutritional factors were known to be important in determining the likelihood of death or complications, and the usefulness of additional information on nutritional status was unclear. To clarify this, the multivariate analysis was performed in a backwards-stepwise fashion with the nonnutritional variables entered first and the nutritional variables entered later, and they were only retained if they significantly added to the predictive power of the nonnutritional variables. The number of complication events was relatively low, and to limit the number of variables considered in the multivariate analysis, a stringent criterion was adopted ($p < 0.05$ in univariate analysis). The models obtained for estimating risk of death and reventilation need to be validated in other studies; however, calculation of the probability of reventilation using the coefficients obtained in the present study is illustrated below.

From the logistic regression equation, the estimated probability of reventilation (P_{rv}) is given by: $P_{rv} = e^{(C)}/(1 + e^{(C)})$. The model coefficients shown in Table 6 can be used to calculate C. Thus $C = (50.162) + (7.454 \times 1 \text{ or } 0) - (2.344 \times \text{BMI}) - (0.085 \times \text{MEP\%})$. (The coefficient for operation type (7.454) is multiplied by one for pneumonectomy, or zero for lesser resection.) Thus if the patient has a BMI of 18 and MEP% is 80%, the estimated risk of needing reventilation after lobectomy is 76% compared to a risk of less than 0.01% if the patient has a BMI of 25 and the MEP% is 120%.

Other Complications

Nutritional status did not appear to influence the occurrence of lesser complications. However, because of the modest numbers of patients and the rarity of some complications such as broncho-pleural fistula, an important effect may have been missed. In this regard it is noteworthy that the only subject with a broncho-pleural fistula in this series was severely nutritionally depleted before the operation (BMI, 16.8; FFMI, 14.2) and subsequently died. Bashir and colleagues [21] made a similar observation regarding the 4 patients in their series that developed broncho-pleural fistulas. Wound infections were particularly uncommon in our patients presumably reflecting good surgical and nursing practices, as well as the routine use of prophylactic antibiotics.

Intercostal Drainage Time

Apart from complications, the main factor causing delay in discharge after lobectomy was the need for lengthy intercostal drainage. Shorter drainage time was associated with higher preoperative lymphocyte count and better preoperative subjective global assessment score (a clinical nutritional assessment). The dominant influence of lymphocyte count on postoperative intercostal drainage time was unexpected and needs to be confirmed in other studies, but it is possible that this reflects the strength of the immune or inflammatory response needed to seal leaks in the lung. Immune function may be impaired by nutritional depletion and this may be manifest by a low lymphocyte count. A low lymphocyte count has been associated with postoperative complications in other series, and this has been interpreted as confirming the importance of immunocompetence in postoperative recovery [22].

Because surgical treatment of lung cancer is the only approach likely to achieve a cure, the number of patients successfully treated needs to be maximized. In the present study where patients were accepted for operations using conventional clinical and lung function criteria, we have shown that the assessment of nutritional status gives further valuable information about the risk of death and the likely need for reventilation after an operation. Simple nutritional assessment is easily and rapidly performed, and consideration should be given to incorporating measurements, such as BMI and FFMI, as well as MEP%, into the routine preoperative assessment of patients with lung cancer.

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