Salvage Intensive Care Following Initial Recovery From Pulmonary Resection: Is It Justified?

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Background. There is little objective evidence concerning the outcome of thoracic surgical patients who suffer postoperative complications. We assessed the outcome and cost of care for patients admitted to the intensive care unit after initial recovery from pulmonary resection in a high-dependency unit.

Methods. In a single surgeon’s practice, over a 3-year period, 28 patients (22 male, median age 66 years old [range 48–80 years old]) required intensive care admission. Preoperative pulmonary function, reason for initial operation, cause of intensive care admission, interventions, and outcome in hospital and at 6 months was studied. The cost of care provided was estimated.

Results. The major reason for intensive care admission was respiratory failure; 61% of patients required mechanical ventilation and 54% renal support. All 4 patients who required both mechanical ventilation and hemofiltration died. Intensive care and 6-month survival were 54% and 36%, respectively. On univariate analysis mechanical ventilation and renal support predicted both hospital mortality ($p < 0.001$ and $p = 0.003$) and 6-month mortality ($p = 0.003$ and $p = 0.01$). Patients who died in intensive care stayed longer (median stay 9 vs 3 days; $p = 0.04$) at a higher cost per patient (median cost $6975$ vs $19,375; p = 0.04$) than those who survived.

Conclusions. Patients who suffer complications after lung resection and require salvage intensive care, particularly mechanical ventilation, have a poor prognosis. In the light of this data the onset of two-organ failure should prompt an informed discussion as to whether escalation of treatment is in the patient’s best interest.


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Although current practice in thoracic surgery varies, there seems to be a shift toward routine extubation immediately after surgery, and the benefits of this approach have been described [1]. However, there is no clear evidence regarding the ideal management of these patients in terms of monitoring and length of stay. With increasingly limited resources and improved techniques, recovery of major pulmonary resection can be performed in high dependency units (HDU), which have the ability to invasively monitor patients thus reducing the usage of scarce intensive care unit (ICU) beds.

Unfortunately, a proportion of patients undergoing lung resection will suffer postoperative complications that could only be managed in an ICU setting. There have been few attempts in the literature to assess outcomes and requirements in this particular group of patients who recovered initially from pulmonary resection but, due to complications, required “step-up care” [2, 3]. There are some data available in the settings of cardiac, general surgery, and medical critical care, including attempts to elaborate predictive models for outcomes [4–6]. Little data are available following lung resection.

We conducted an audit of resource usage and outcomes of patients who initially recovered from pulmonary resections but required step-up care following complications.

Patients and Methods

A review of a single surgeon’s 3-year practice (September 1998 to November 2001) identified 391 patients who underwent various forms of pulmonary resection for benign and malignant disease. All patients were initially recovered in a thoracic HDU. A total of 28 patients (7.1%; 22 male, 6 female; median age 66 years old [range 48–80 years old]) required admission to the ICU following initial recovery in the HDU (Table 1).

During this period of time, patients undergoing thoracic surgical procedures were routinely transferred from operating theater recovery to an HDU where invasive methods of monitoring are provided (continuous arterial and central venous pressure monitor, arterial blood gases analyses, urinary output). Analgesia is routinely administered using a thoracic epidural catheter until the patient is ambulatory. Early physiotherapy and mobilization is encouraged and provided by specialist teams. Discharge from the hospital occurred following an evaluation by medical, nursing, physiotherapy, and occupational therapy staff and requires the patient to be self caring and ambulant without aid. Various forms of step-up care such as intravenous dopamine infusions, noninvasive ventilation, and invasive nutritional support can be provided on the HDU. Patients who required intubation and ventilation, more than one inotrope or hemofiltration have to be

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transferred to ICU where responsibility for their care is shared by the surgical team and intensivists.

The indication for initial surgery was intrathoracic malignancy in 23 patients (18 nonsmall-cell lung cancer and 5 malignant pleural mesothelioma), and benign disease in 5 patients (4 for end-stage emphysema and 1 aspergilloma). In total, 12 lobectomies, 5 bronchoplastic lobectomies, 5 extrapleural pneumonectomies for mesothelioma, 4 unilateral video assisted thoroscopic lung volume reductions, 1 pneumonectomy, and 1 anatomic segmentectomy operation was carried out.

Preoperative assessment of patients followed guidelines recommended by the British Thoracic Society in patients with lung carcinoma [7], published standards [8], and our own research of lung volume reduction surgery for end-stage emphysema [9]. Preoperative median forced expiratory volume in 1 second (FEV1) was 1.6 L (range 0.47 to 3.25 L), median FVC 2.7 L (range 1.4 to 4.9 L), and a median preoperative predicted FEV1 percentage of 66% (range 15% to 95%). Median preoperative body mass index (BMI) was 21.7 (range 17.6 to 29.6). Five patients (18%) were more than 75 years old at time of surgery, 17 patients (61%) had a FEV1 of less than 70% of predicted, and in two patients (7.9%) BMI was lower than 18.5 [10].

An estimated cost of hospital care per patient was calculated using a variant of the “weighted hospital days” method of Rapoport and colleagues [11]. In this system a non-ICU hospital day is given the value of one unit (U) and ICU days are “costed” as a multiple of that unit. The first day is 4 U, the second is 3 U, and every subsequent day is 2 U. This takes into account the fact that ICU stays use more resources than other days in a hospital, and the highest resource use tends to come at the beginning of the stay. We modified this method to allow for the fact that the institution of hemofiltration adds significantly to the costs incurred on the ICU and, therefore, every day of hemofiltration was costed at 3 U. We estimate the cost of one unit to be $775.

### Table 1. Total Number of Each Type of Resection Undertaken by the Surgeon During the Study Period

<table>
<thead>
<tr>
<th>Operation</th>
<th>Total Number of Patients</th>
<th>ICU Admission (%)</th>
<th>Hospital Death</th>
<th>6-Month Death</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lobectomy</td>
<td>200</td>
<td>12 (6.0%)</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>Sleeve lobectomy</td>
<td>39</td>
<td>5 (12.8%)</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>EPP</td>
<td>24</td>
<td>5 (20.8%)</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Pneumonectomy</td>
<td>42</td>
<td>1 (2.4%)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Sublobar resections</td>
<td>47</td>
<td>1 (2.1%)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>VATS LVRS</td>
<td>39</td>
<td>4 (10.2%)</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>391</td>
<td>28 (7.1%)</td>
<td>13</td>
<td>18</td>
</tr>
</tbody>
</table>

### Table 2. Primary Cause of ICU Admission

<table>
<thead>
<tr>
<th>Cause of Admission</th>
<th>Number (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respiratory failure</td>
<td>14 (50%)</td>
</tr>
<tr>
<td>Cardiovascular failure</td>
<td>7 (25%)</td>
</tr>
<tr>
<td>Haemorrhagic conditions</td>
<td>4 (14%)</td>
</tr>
<tr>
<td>Sepsis</td>
<td>3 (11%)</td>
</tr>
</tbody>
</table>

ICU = intensive care unit.

Univariate analysis of qualitative data were performed with the $X^2$ test, and for quantitative data with the Student’s $t$ test if variables were normally distributed and Mann-Whitney if they were not. Variables with $p$ values less than 0.1 on univariate tests entered a binomial forward logistic multivariate regression analysis to assess their weight as independent predictors of outcomes. Significance was considered when $p$ was less than 0.05 throughout.

At the time this study was performed the local policy was that anonymous, retrospective, case note reviews were exempt from the requirement for local hospital ethics committee approval.

### Results

#### Indications for ICU Transfer

Following initial recovery from lung resection, 7.1% of patients required salvage mechanical ventilation. The median HDU stay before transfer to ICU was 5 days (range 1 to 60 days). The immediately recognized indications for the transfer are listed in Table 2. Respiratory failure was the primary reason for transfer to the ICU in 50% of patients. Other causes were cardiovascular failure, hemorrhagic conditions, and sepsis. Five patients were successfully resuscitated from cardiopulmonary arrest and 1 patient suffered a myocardial infarction before admission.

Seven patients (25%) required additional operations during their postoperative course. Four patients underwent thoracotomy (2 patients for control of hemorrhage, 1 patient for repair of a dehisced diaphragmatic patch, and 1 patient for decortication of a postoperative empyema). Three patients required laparotomy (for control of upper gastrointestinal hemorrhage in 2 patients, and for repair of strangulated inguinal hernia in 1 patient).

#### Supporting Measures in ICU

Mechanical ventilation after ICU admission was required in 17 patients (61%). A surgical tracheostomy was performed in 10 of these patient. In 2 other patients mechanical ventilation was avoided by the use of bronchoscopy and insertion of minitracheostomy. The remaining 9 patients (32%) avoided invasive respiratory support or procedures.

Inotropic support (either adrenaline, noradrenaline, or high-dose dopamine infusion) was used in 15 patients (54%). In 10 of these patients a combination of drugs was used. None of the patients required the use of an in-
traaortic balloon pump. The remaining 13 patients (46%) were invasively monitored without inotropic support.

Renal failure was evident in 15 patients (54%) during their ICU stay requiring support in the form of continuous infusion of diuretics and low-dose dopamine in 11 patients (39%), and necessitating renal replacement therapy in 4 additional patients (14%). No patient required ICU admission primarily to treat renal failure. Thirteen patients (47%) did not require specific measures for renal support.

Invasive nutritional support was used in 16 patients (57%): enteral feeding in 9 patients (32%) and parenteral feeding in 7 patients (25%). Twelve patients (43%) were fed orally without need for invasive nutritional support while on the ICU.

Fourteen patients (50%) required intravenous antibiotics for clinically significant methicillin-resistant *Staphylococcus aureus* (MRSA) infection diagnosed at one point during their hospital stay.

### Outcomes and Predictors of Outcomes

Thirteen patients (46%) died during their ICU stay. The remaining 15 patients (54%) were discharged from the ICU back to the ward after a median stay of 3 days (range 1 to 35 days). All these patients were eventually discharged home after a median total hospital stay of 23 days (range 11 to 90 days). All patients were followed up in our unit and at 6 months the overall mortality was 64% (18 patients). Five of 15 patients discharged from the hospital died within 6 months. Four of the deaths were due to a recurrence of the malignant disease (3 nonsmall cell lung cancer and 1 malignant pleural mesothelioma), the other death was due to pneumonia.

Of the 11 variables tested, on univariate analysis, only the need for mechanical ventilation on admission to the ICU due to complications (\( p < 0.001 \)) and subsequent requirement for renal support (\( p = 0.003 \)) were predictors of hospital mortality (Table 3). All 4 patients who re-
quired mechanical ventilation and hemofiltration died in the hospital. At 6 months, only 10 patients were alive (36%). Need for mechanical ventilation and renal support were the only significant predictors of mortality at 6 months ($p = 0.003$ and $p = 0.01$, respectively). Renal failure was the only variable that maintained significance on a binary logistic multivariate regression analysis for hospital death: hazard ratio 16.5 (1.1–25.0 95% confidence interval [CI]; $p = 0.04$). Age, sex, preoperative pulmonary function, extent of resection, diagnosis, and need for an additional operation, inotropic support or invasive nutritional support were not predictors of poor outcome.

Overall median ICU stay was 3 days (range 1–80 days) and median total postoperative stay was 21 days (range 5–91 days). Median ICU stay of the 13 patients who died in hospital was 9 days (range 1–80 days), which was longer than patients who were eventually discharged home (median of 3 days, range 1–35 days). There was also a higher estimated hospital cost per patient in the mortality group than the 15 patients who survived (median $\$6975$ vs $\$6975$ [13 Patients] $p = 0.04$). There was no significant difference in the median total hospital stay when comparing those who died with those who survived (Table 4).

**Comment**

The implications of the implementation of invasive measures to support patients with severe complications requiring ICU care are twofold: the emotional suffering of patient’s relatives during interventions that may only lead to a delay in the inevitable outcome; and the use of the valuable and limited resources available. It is estimated 20% of hospital costs are spent in the ICU [12] and that more than 50% of the ICU resources are expended on patients who do not survive [13, 14].

Patients who initially recover after pulmonary resection and then require ICU care have a poor outcome [2, 3]. Respiratory failure and the need for mechanical ventilation are important predictors of outcome, both on the ICU and at 6 months. Requiring renal support also predicts poor ICU outcome. The combination of mechanical ventilation and hemofiltration was universally fatal in our patients. A large number of factors that predict ICU outcome in other situations, such as age, preoperative pulmonary function, need for an additional operation, original diagnosis, inotropic requirement, nutritional support, and extent of resection, are not predictive in our series. A recent study of patients ventilated for more than 24 hours on a general ICU found an in-hospital mortality of 47.4% and a 1-year mortality of 64.7% [15]. The results in our patients were a little worse (76% in hospital and 88% mortality at 6 months), but within a similar order of magnitude.

There are few previously reported series on thoracic surgical patients postpulmonary resection. Desiderio and associates [1] reported a 3.1% ICU admission rate that suffered a hospital mortality of 29%. Their series includes a general thoracic surgical caseload, not just patients postlung resection. As with our patients, one-half of their admissions were due to respiratory failure and there was a wide range of ICU stay (1 to 68 days, median 8 days). The authors do not provide any postdischarge data. Hirschl-Schulte and colleagues [2] reported respiratory failure requiring mechanical ventilation in 4.4% of a series of patients recovering from lobectomies and pneumonectomies for bronchial carcinoma. They report an in-hospital mortality of 50% and a 1-year mortality of 81% (13 of 16 patients), which is comparable to our results. Of the 5 patients who died within 1 year of discharge, all suffered from recurrent malignancy. Although, in our study, there was no statistical relationship between malignant histology and 6-month postoperative survival, 4 of 5 patients who died after discharge suffered from recurrent malignant disease. The finding of a 76% mortality rate in patients ventilated postpneumonectomy, in a series reported 10 years ago, continues to be the case today [3]. In this study renal failure did not predict in-hospital mortality but the mortality rate of patients with renal failure was only 28%, which is much lower than the 76% mortality rate that we reported. There was no association between postoperative mortality and increased age. Filaire and associates [16] investigated hypoxemia after pulmonary resection and found that there was no significant correlation between preoperative lung function or age and postoperative PaO$_2$. Percentage predicted postoperative FEV$_1$ and a number of resected subsegments were found to be predictors of a need for mechanical ventilation after lobectomy. Unfortunately, the authors make no comment on the outcome of the patients who were ventilated in this study. In their comparison of patients ventilated after major lung resection with or without an initial period of noninvasive ventilation, Auriant and associates [17] reported an in-hospital mortality rate of 37.5% (9 of 24) for patients in the traditional arm of the study. This mortality rate was unchanged at 120 days postoperation.

When drawing conclusions from our data we must acknowledge that the number of patients studied is

| Table 4. Comparison of Length of Stay and Cost of Care for Hospital Survivors Versus In-Hospital Deaths |
|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-----------------|
| All 28 Patients | Hospital Survivors (15 Patients) | Hospital Deaths (13 Patients) | $p$ Value |
| ICU stay | 3 (1 to 80) days | 3 (1 to 35) days | 9 (1 to 80) days | 0.08 |
| Hospital stay | 21 (5 to 91) days | 22 (11 to 91) days | 17 (5 to 91) days | 0.6 |
| Cost of care | $\$6975$ (3100–186,775) | $\$6975$ (3100–56,755) | $\$19,375$ (3100–186,755) | 0.04 |

Estimated cost of ICU care per patient in both groups. Data presented as median (range).

ICU = intensive care unit.
limited. The difference in mortality rate of those ventilated compared with those who did not require invasive mechanical ventilation is striking even with our relatively small sample. All the patients in our study had standard preoperative spirometry to determine fitness for the operation, but only those with borderline spirometry underwent further assessment and, therefore, we could not include preoperative factors such as gas transfer factor or maximal oxygen consumption in our analysis of possible predictive factors. There are a small number of patients who, although unwell enough to be transferred to the ICU, remained on the HDU and we do not have any data for these patients. By using a group of patients who had all undergone pulmonary resection we sought to study a more homogenous group than that of a general thoracic surgical practice. We chose not to analyze the data by operation, because the low numbers would have made the results of limited value. Studies have indicated that impaired nutritional status does predict death and reintubation after resection for bronchial carcinoma [18]. In our study we had to analyze secondary factors (need for nutritional support on ICU) rather than primary preoperative data (BMI for nutritional support in ICU) rather than primary preoperative variables, but we could not include preoperative factors such as gas transfer factor or maximal oxygen consumption in our analysis of possible predictive factors. There are a small number of patients who, although unwell enough to be transferred to the ICU, remained on the HDU and we do not have any data for these patients. By using a group of patients who had all undergone pulmonary resection we sought to study a more homogenous group than that of a general thoracic surgical practice. We chose not to analyze the data by operation, because the low numbers would have made the results of limited value. Studies have indicated that impaired nutritional status does predict death and reintubation after resection for bronchial carcinoma [18].

In our study we had to analyze secondary factors (need for nutritional support in ICU) rather than primary preoperative data (BMI < 18.5) because only 2 of our patients had a BMI < 18.5. We did not find that nutritional support on ICU predicted death in our patients.

Precise costing of care is difficult in the United Kingdom, and so we estimated the cost of care using the “weighted hospital days” formula devised to allow calculation of costs from resource usage when charges or accounting costs are not available. We realize that this has its limitations. It is unsurprising that patients who die on ICU stay for longer periods than those who survive, and that they cost more as they require more complex interventions.

It was pleasing to note that all patients who were discharged from ICU back to thoracic HDU were discharged home, although we have reported that one-third of these patients died within 6 months of discharge. The overall 6-month mortality rate of the patients in our study was 64%, rising to 88% if we consider only those who were intubated and ventilated. We believe it is important to consider this long-term outcome, rather than just immediate chance of surviving ICU when considering introducing ventilation and renal support. In Korkela and associates’ [19] study of the treatment of acute renal failure in patients on ICU in Finland, the 6-month mortality was 55% and the cost per survivor was $80,000 but complete functional and physical recovery was seen in the patients at 6 months and, therefore, the authors believe such intervention cost effective. The resources needed to treat our patients are great and we believe that the outcome does not justify the expenditure.

It is known that noninvasive positive pressure ventilation (NPPV) significantly reduces the need for invasive mechanical ventilation, and both in-hospital and 3-month postoperative death rates in patients who suffer acute respiratory failure postlung resection [16]. The mechanism remains unclear, although NPPV certainly avoids complications of invasive mechanical ventilation, such as tracheobronchial bacterial contamination and bronchopleural fistula [15]. We believe that increased use of noninvasive ventilatory support on the HDU will reduce the need for invasive ventilation in our patients and, hence, reduce the mortality rate of patients with respiratory failure.

The withdrawal of life support is a complex issue but occurs frequently in the ICU setting. In a 1990 survey of members of the critical care section of the American Thoracic Society, 80% of its members stated they had withheld or withdrawn treatment on the basis of futility [20]. In their study of two American ICUs, Prendergast and colleagues [21] found that the decision to forgo life-sustaining therapy preceded 90% of ICU deaths. In 44% of patients where futility was cited as the reason for the decision to withhold life support the median predicted ICU survival was 5% (range 1% to 50%) [21]. Whether a 12% 6-month survival for patients ventilated would be considered a futile outcome would depend on the individual circumstances, but it should be considered carefully by the physician in consultation with the patient or their surrogate before ventilation was commenced. Certainly physicians have a duty not merely to furnish all possible care, but are under professional and social sanctions to provide only those therapies that are beneficial, avoid harm, and to allocate medical resources wisely [22].

The combination of mechanical ventilation and hemofiltration in patients postlung resection was invariably fatal in our study, although this occurred to only 4 patients. Therefore, we believe that escalating care by commencing hemofiltration in a ventilated patient, postlung resection should be prefaced by careful consideration of the likely costs and outcome. We acknowledge that the number of patients studied means the sample is too small to support a change in practice, but we hope we have provided the stimulus for further data collection about this challenging group of patients. We have found that the requirement for mechanical ventilation after initial recovery from pulmonary resection is unpredictable, by commonly measured preoperative variables, but in itself predicts a poor short-term and extremely poor long-term outcome. The high cost and poor outcome of salvage intensive care following pulmonary resection and HDU care makes such escalation difficult to justify.

References

5. Chen LM, Martin CM, Keenan SP, Sibbald WJ. Patients readmitted to the intensive care unit during the same
22. Luce JM. Physicians do not have a responsibility to provide futile or unreasonable care if a patient or family insists. Crit Care Med 1995;23:760–6.

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